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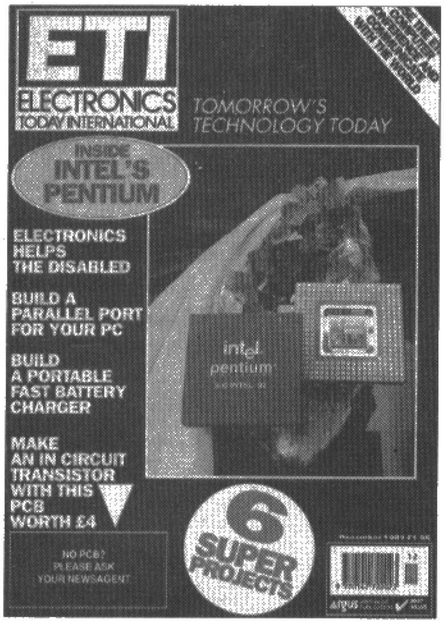

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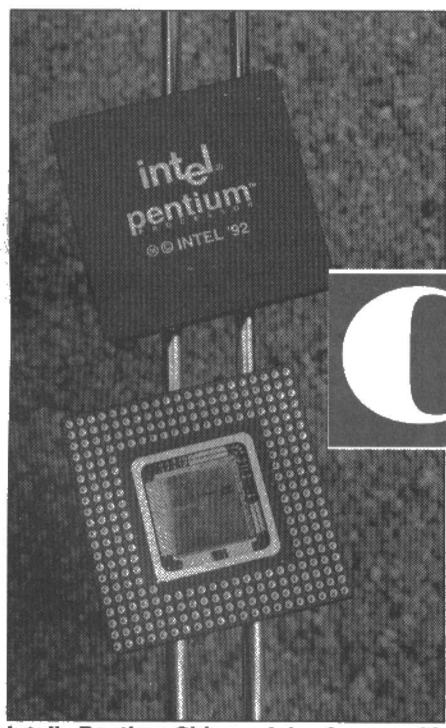

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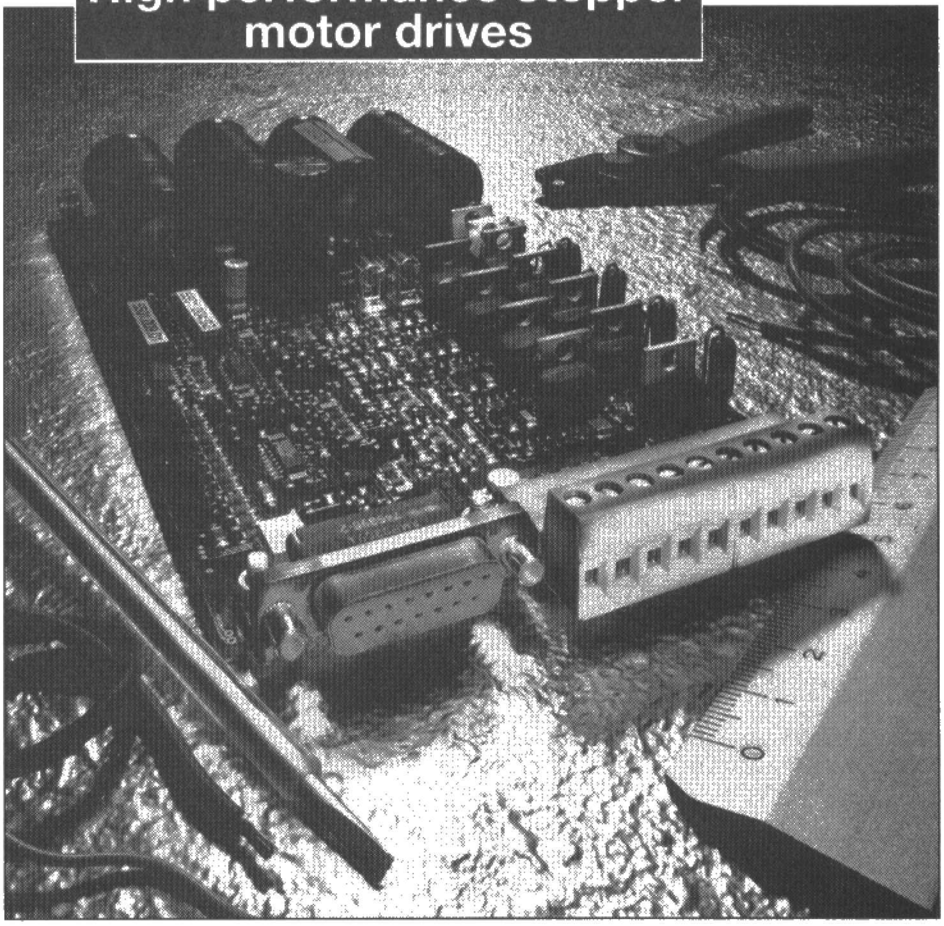
We will be looking at the way in which electronics can help the environment, through improving energy efficiency, enabling the use of alternative energy sources and making it possible for large numbers of people to work from home. We will also be looking at the use of computer software in electronics and how your computer can be used to help design better circuits.

There will also be plenty of interesting projects, including a ROM emulator for the microcomputer experimenter, a versatile valve amplifier for guitar players, a cycle alarm to stop anyone tinkering with your bike and a useful piece of test equipment, a logic pulser generator. Plus more on MPU basics and computer interfacing.

ETI NEWS

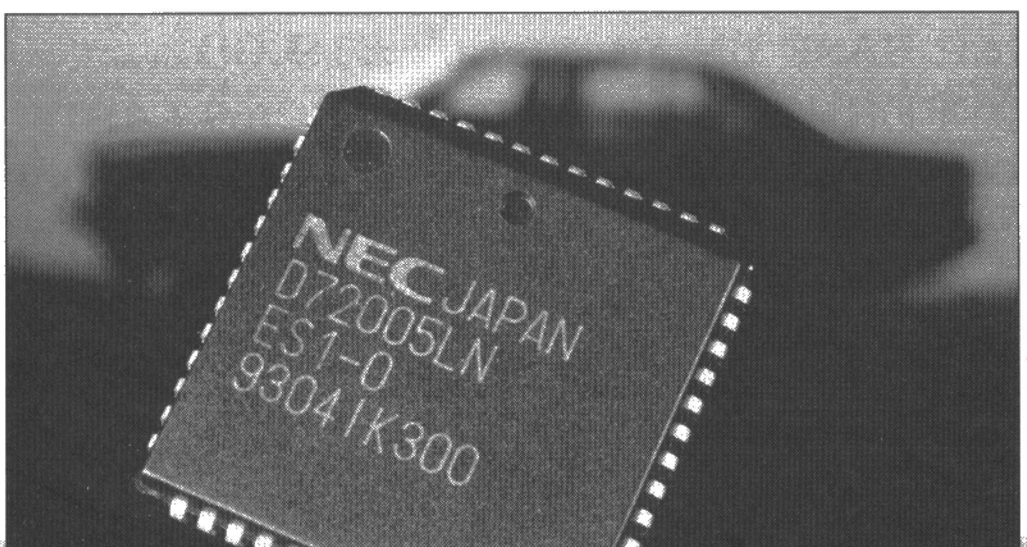
High performance stepper motor drives



From Poole based stepper motor specialists, Digiplan, comes a new family of high performance stepper motor drive modules. Available with 2A, 3A, or 5A output capability the drives are suitable for use with any standard 2-phase hybrid or permanent magnet stepper motor, having 4, 6, or 8 leads and featuring user-adjustable current limiting for optimal motor matching.

All these drivers can operate in full or half step mode, providing 200 or 400 steps/rev resolution from a standard 200 step rotary stepper motor, and can also be used with linear stepper motors.

For more information contact Digiplan on 0202 699000



Special communications chip for noisy environments

NEC has just launched a new controller area network (CAN) driver chip, the uPD72005. This chip has been designed to enable automotive engineers to simplify vehicle body design by replacing many separate control lines with a single 2-wire data bus.

The CAN standard is a robust high-speed serial communications protocol designed for noisy real-time control applications. It passes the signals securely between the master control and sub-system without loading either the sub-system or central processor. As such, although designed for automotive applications, it can be used in any system where noise and wiring complexity is a problem.

This chip has a 160 byte on-chip memory and can store 28 messages. It has fully intelligent message handling, enhanced diagnostics and error trace functions, readable bus error counters and a received message time stamp.

For more information contact NEC on 0908 691133.

Smoke alarm kit from Maplin

New from Maplin Electronics is a smoke alarm, designed to operate with the 12V supply from the control panel of a security system, and provide an alarm signal via a set of relay contacts. The contacts are normally closed in the 'no smoke' condition.

The alarm has a sound output of 85dB (minimum) at 10ft, and an LED flashes every two seconds when smoke is detected. The LED normally flashes every 40 seconds to provide indication that the unit is on. The test facility, which can be operated locally or remotely, checks the sensor, electronics and alarm.

This kit is easy to assemble and comes complete with all components, including the relay, case, etc. It is available from any Maplin shop or by mail order, price £19.93 plus VAT.

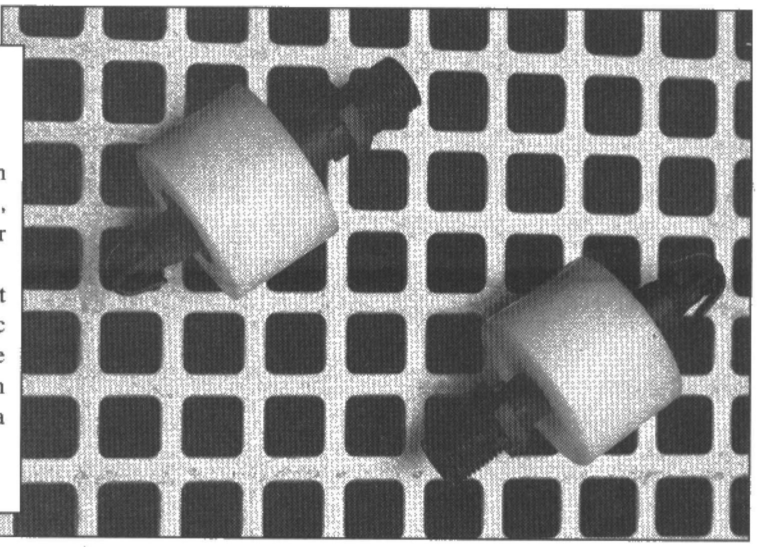
For further information contact Maplin on 0702 554161.

New fluid sensors from Gentech

A new range of compact vertical fluid level sensors has been launched by Gentech International. Measuring less than 60mm, the sensor offers proven reed switch reliability and a facility for high or low liquid level sensing simply be reversing the float.

Supplied with normally open, or normally closed contact action, these sensors have a maximum contact rating of 15W dc and a maximum switching voltage of 100V dc (250V rms). The sensors come with a 1/8in NPT thread fitting and are made from polypropylene. These sensors will work with liquids down to a SG of 0.70.

For further details contact Gentech on 0465 3581



Optical computers take a step forward

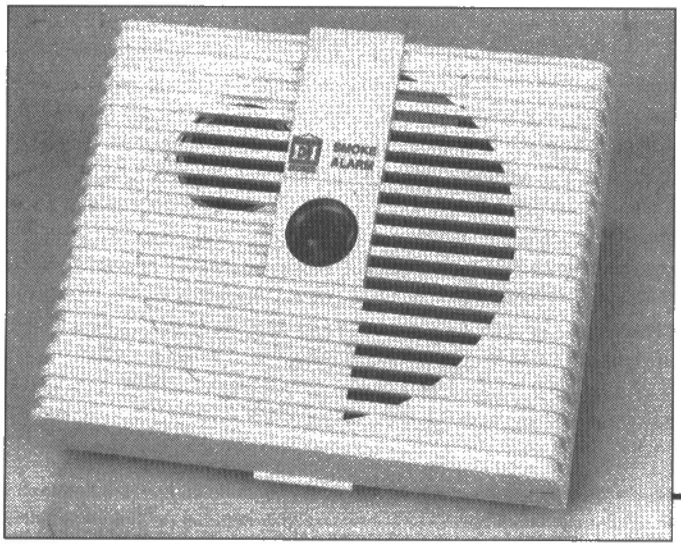
In the University of Colorado's Optoelectronic Computing Systems Center what is claimed to be the world's first optical computer is at work. This almost completely optical computer stores and manipulates its instruction and data as pulses of light, rather than pulses of electricity.

This system, the bit-serial optical computer, or BSOC, is an extremely simple computer with just 128 bytes of memory. Functionally, it can do little more than basic switching, counting and arithmetic, in other words about as much as the world's first electronic computer built by the University of Manchester in 1948.

What BSOC does show is that optical computers can be built, although the technology employed means that they are still much slower than their electronic counterparts. BSOC operates at just 50MHz, but the technology used to create optical switches and flip-flops is still very new - within a few years we could see dramatic improvements in capability.

The optical switches used in BSOC are fabricated by diffusing titanium through the surface of a clear crystal of lithium niobate to form two channels for the light. When a voltage is applied the optical pathways are parallel, when the voltage is removed they cross. The fact that these switches are a hybrid of electronics and optics accounts for their ineffeciency.

The memory used by BSOC is, however, purely optical in nature. It consists of a delay line constructed from coils of optical fibre. This means that where an electronic computer will fetch data or instructions from a memory address, BSOC will wait for that data or instruction to come to it.



Low cost hand held frequency meter

From Huntingdon based Thurlby-Thandar Instruments Ltd, comes a hand held, battery powered, 1.3GHz frequency meter that costs less than £100. Despite its compact size and low cost, the PFM1300 incorporates many advanced features normally associated with sophisticated bench instruments.

The PFM1300 uses the reciprocal counting technique to achieve a high measurement accuracy for all frequencies. The system yields at least seven digits of resolution per second measurement time, and can resolve low frequencies to 0.001mHz.

The measurement range is 5Hz to 1300MHz, with excellent sensitivity and a low pass filter can be selected when required. Signals can also be displayed in terms of period as an alternative to frequency. There is a 'hold' key to retain readings on the 8-digit LCD display.

The PFM1300 costs £99 and further details can be obtained from TTI on 0480 412451.

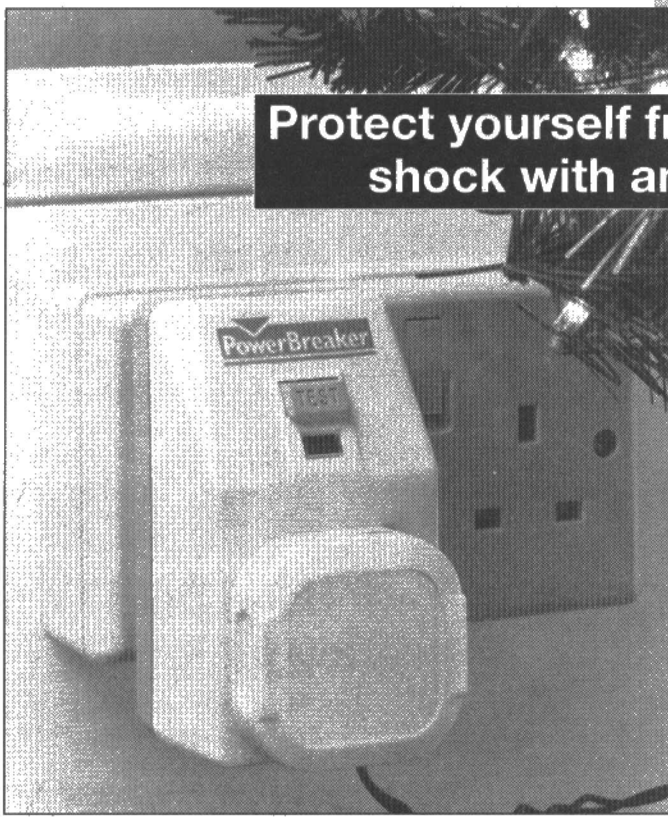
Bright future for electroluminescent polymers

Physicists at the University of Cambridge have developed a new display technology which is generating an enormous amount of excitement in electronics companies around the world. The technology is based upon the light emitting properties of an organic polymer called polyphenylenevinylene, or PPV for short.

Very thin films of purified PPV emit light when just a few volts are applied across it. Unmodified PPV emits surprisingly large amounts of greenish light, indeed it is about 10% efficient in converting electrical energy into light as opposed to only 1% for LEDs. The researchers have been able to create derivatives of PPV which can generate light in a wide range of other colours including red and a very good blue.

Not only are displays based on PPV very efficient at generating light, they are also capable of generating light which is more than ten times as bright as that generated by a CRT tube. This means that PPV based displays are ideal for applications such as emergency lights and signs. They also offer high reliability and stability, products with a 100,000 hour life should be standard.

Expect to see prototype PPV based displays within the next year and commercial products from some of the big US and Japanese companies with two or three years.



Protect yourself from a fatal shock with an RCD

A mains shock is always extremely painful and can be fatal, but it is easy enough to protect yourself and your family from the risk of receiving an accidental electric shock. All that is needed is an RCD plug or adapter, such as manufactured by PowerBreaker.

RCD stands for Residual Current Devices and they are unique because, unlike fuses and conventional circuit breakers, they are specifically designed to safeguard human life as opposed to safeguarding the mains cable.

PowerBreaker RCDs are now available from many high street outlets and cost £21.99 for a 13A adapter.

New microprocessor training course

Polar Instruments Ltd has just launched a new package for training technicians in the principles of microprocessor based systems. The course is built around a fault testing instrument, a working processor trainer and a 200 page self-instructional manual.

The course provides a means of understanding the 'real-world' hardware characteristics of processor-based boards. It takes two or three days to complete after which students should be acquainted with all the fundamental operational principles of processor based electronic systems. An understanding which should equip them with the conceptual tools to fault find in development, manufacturing test, and maintenance environments.

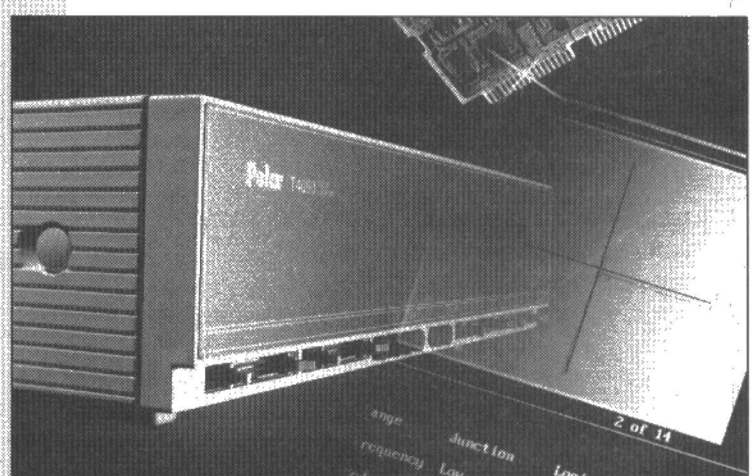
The course package is priced at £795 and can be reused for as many students as necessary. For further details contact Polar on 0481 53081.

PC based analogue signature analyser

A new type of analogue signature analyser has been developed by Polar Instruments Ltd. Based on a PC, with virtual instrument user interface, it automates the fault finding function by means of a powerful signature digitisation and comparison technique.

This technique eliminates the need for expert electronics knowledge of the circuit under test and speeds the component level diagnostic process, allowing companies to implement far more cost effective electronics maintenance strategies.

This is a very advanced and sophisticated piece of equipment, but one which nevertheless offers manufacturers a very cost effective solution to every aspect of testing, in particular in low volume manufacturing operations. The T4040 costs £2995 and further information can be obtained from Polar's distributor, Whingate Test Services of Poole on 0202 605239.



Blue laser breaks the data storage barrier

The short wave length of blue light compared to that of red means that it can be focused to a much smaller spot. This means that optical recording media based on blue laser light can be constructed with a much higher density of data storage than a similar system utilising infra-red laser light. With blue light the amount of data stored on a disk can be more than quadrupled.

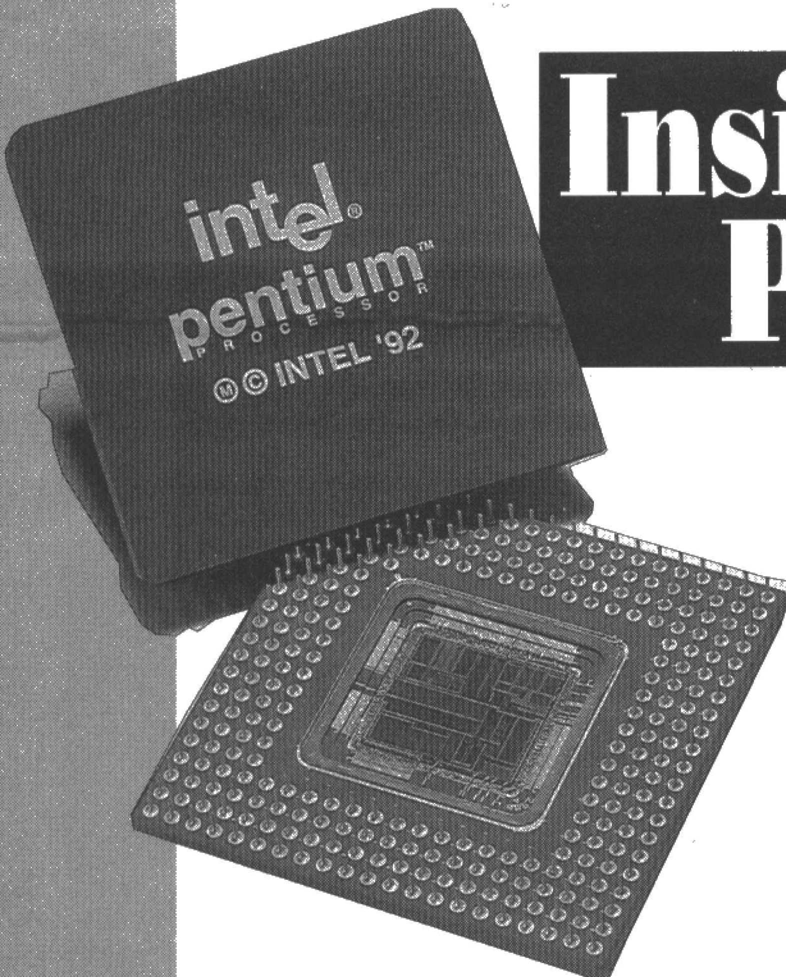
A blue light semiconductor laser has thus, for many years, been a goal for researchers, a goal which has finally been achieved by a team at IBM's Almaden Research Centre in California.

The technique which they have employed to generate blue laser light consists of feeding a beam of infra-red laser light generated by a conventional gallium arsenide diode laser into a special frequency doubler. With the aid of special feedback controls this frequency doubler generates blue laser light at a sufficiently high power rating for use in optical data storage systems.

So far the IBM team has succeeded in creating a magneto-optical disk system based on the blue semiconductor laser which is capable of storing 6.5 Gigabytes of data on a single double sided 5.25in optical disk. There are, however, a great many problems which still need to be overcome before such high capacity disks are available commercially.

High density optical disks will require new high precision optical and mechanical systems. Accurately positioning the read/write head over a data track becomes much harder as the track becomes smaller. There are also increased problems from environmental effects such as dust, problems which will require new encoding and error detection/correction techniques.

Inside Intel's Pentium



The PC superprocessor

The Pentium microprocessor chip, launched by Intel earlier this year and now finding its way into many top range PCs, is one of the most complex integrated circuits ever designed and produced. The silicon chip itself is 16mm square and contains over 3.1 million transistors packaged into a massive 2.16in square, 273 pin grid array package. The standard version operates at 60MHz, draws 13W of power and is fabricated using an 0.8micron BiCMOS process.

The Pentium is, without a doubt, an extremely powerful and complex processor chip. Indeed, as the table in **Development of Intel CPUs over the years** shows it is, in computer processing terms, over 150 times as powerful as the 8086 processor used in the first generation of IBM PCs, and in terms of circuit complexity, in other words the transistor count, over 105 times more complex. So what is involved in all this complex circuitry and why is it so powerful? Also, what does the future hold for this chip and for the next generation of processor chips?

The Pentium design philosophy

The Pentium is the latest in a long line of compatible microprocessor chips from Intel, a line which made its first appearance fifteen years ago in June 1978, with the launch of the 8086. Since then a new generation of microprocessor, each more powerful than the last and yet all capable of running the same software, has appeared at about four yearly intervals.

All these processor chips have been based upon a vary conventional computer architecture which uses a large and complex instruction set to perform a wide range of computational operations. They are a category of computer refereed to as CISC, or Complex Instruction Set Computer, machines.

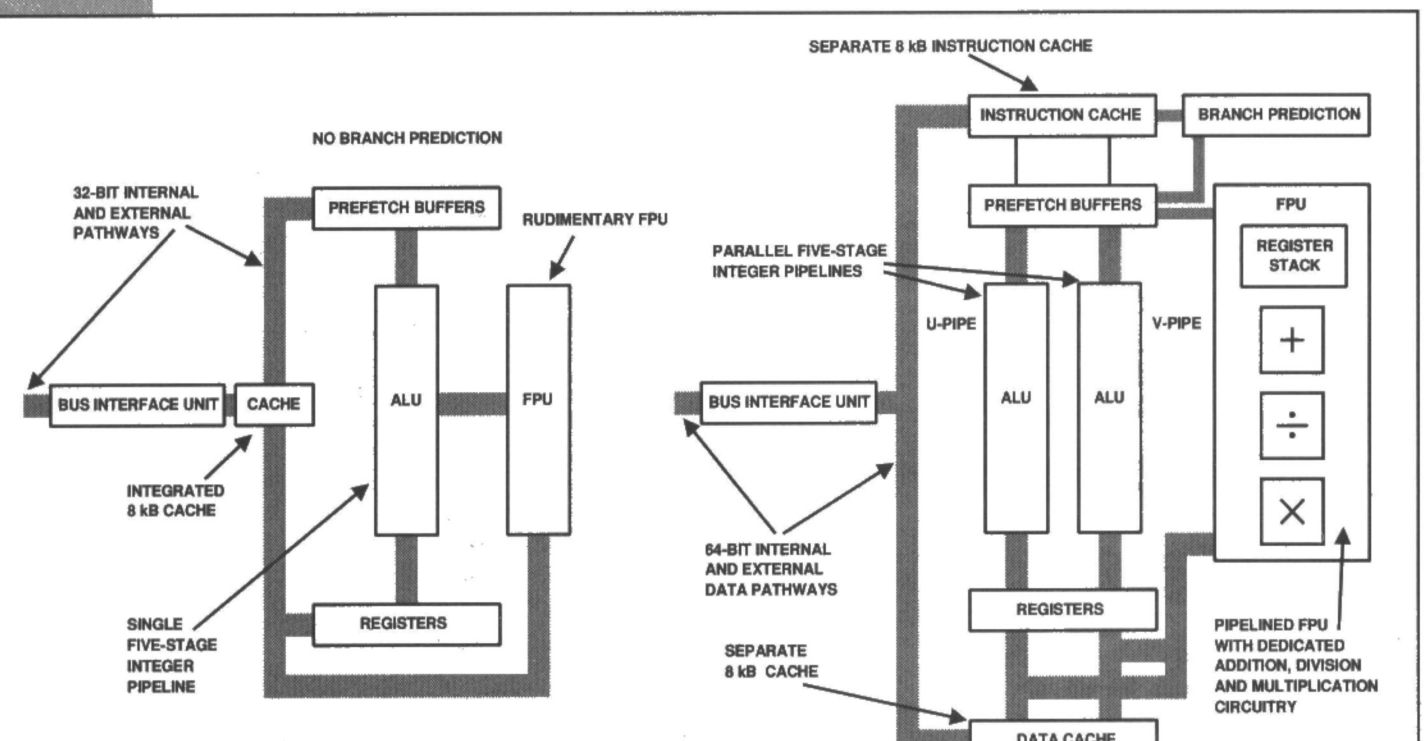


Fig.1 Comparison of 486 and Pentium architectures

However, a complex instruction set also means complex circuitry to decode these instructions and perform the requisite operations. This circuitry allows the processor to carry out operations such as multiplying two numbers together, operations which would otherwise have to be done in software. The result is that a CISC processor achieves high processing throughput in mathematically intensive operations, by using hardware circuitry to perform all but the most complex instructions.

Fifteen years ago CISC architecture was the only viable technique available to Intel's chip designers, so the 8086 was a CISC processor. Within the last five years, however, new architectures have been developed, in particular the RISC, or Reduced Instruction Set Computer, architecture. These new architectures offer very high processing speeds in applications which are not mathematically intensive - see **RISC Vs CISC**.

But the enormous popularity of the IBM PC and the large number of software packages written for 8086 based systems, mean that Intel has been forced to keep software compatibility throughout all five generations of its processor chips. A program written for the 8086 will also run on the 80486, or the Pentium, and it will run a lot faster, but will still employ the same instruction set.

This need for upward and downward compatibility has meant that Intel's designers have, to a large degree, been held hostage by the previous designs. So, in order to increase processor power they have had to resort to using several different techniques. These are increasing the clock speed, increasing the width of the data bus and most recently, introducing techniques which allow two instructions to be computed at the same time.

Probably the most dramatic increase has been in clock frequency, up from just 4.2MHz on the early 8086 based PCs to over 66MHz on a new Pentium based system. Data bus widths have increased less dramatically, up from 16 bits wide on the 8086 to 64 bits wide on the Pentium. The reason why data bus widths have not increased so dramatically is simply that, generally speaking, increases in bus width translate directly into increases in component count. However, both these techniques have in combination accounted for a lot of the improvements in processing speed, but not without raising a number of problems for both the chip designers and those utilising the chip within a computer system - see **Pentium design constraints**.

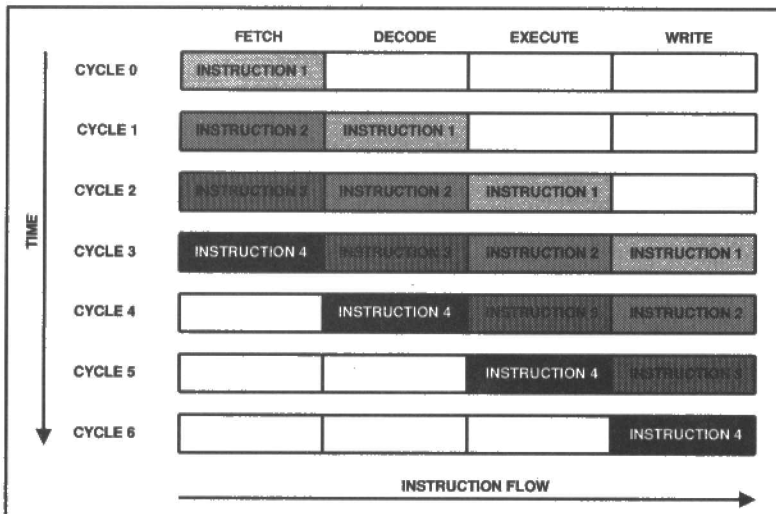


Fig.2. A simplified RISC pipeline

Development of Intel CPUs over the years

The first sixteen bit CPU designed and produced by Intel was the 8086, and it made its debut in June of 1978. It was launched into a personal computer world dominated by eight bit processors, the Z-80 with its CP/M operating system, and the 6502 used in the AppleII and in the Commodore PET and C64. For a while, usage of the 8086 was confined to low volume specialist computers and control equipment, but it was the processor chip chosen by IBM for its new personal computer.

The IBM PC was the mainframe giant's attempt to regain business lost to the new personal computer companies such as Apple. The choice of the 8086 was a gamble, since it was a new processor chip with no existing software support. However, the fact that it was produced by IBM meant that the PC was seen by software producers as a guaranteed commercial success, a hunch which proved correct and which established the PC as a standard for personal computing, and the 8086 as the standard processor chip for the PC.

The eight bit processors soon disappeared from use leaving users with the choice of the 8086 used in the PC or the 68000 used in the new Apple Macintosh that was produced in response to IBM's PC. As software became more sophisticated, so there was an increased demand for more processing power and Intel produced the more powerful 80286. Then in response to the continuing demand for faster processors, the 386, the 486 and now the Pentium, on average a new generation of chip every 44 months.

The following table shows how these successive generations of Intel processor chips have grown in power and complexity over the fifteen years since the 8086 first appeared and into the future with the P6.

8086	June 1978	.75MIPS	29,000 transistors
80286	February 1982	2.66MIPS	134,000 transistors
80386	October 1985	11.4MIPS	275,000 transistors
80486	August 1989	54 MIPS	1.2million transistors
Pentium	March 1993	112 MIPS	3.1million transistors
P6	1995?	200+MIPS	10million transistors

MIPS stands for Millions of Instructions Per Second, and is a standard measurement of computer power.

The Pentium design

The first thing to note about the Pentium is that the designers have added a few instructions to allow programmers to fully utilise some of the new features of this processor chip. These features include the multiprocessing cache coherent protocol, a CPU identification instruction and an eight byte compare and exchange instruction, for fast sorting. However, these additions aside, the instruction set of the Pentium is the same as the 486, and thus fully software compatible.

If we look at the architecture of the Pentium in comparison with that of the 486, see Fig.1, we can see that there is an enormous difference. The most obvious is that there are two arithmetic logic units, ALUs, in the Pentium as opposed to one in the 486. Each ALU in both chips is more or less identical, with the same five stage integer pipeline design. This is a design where the instructions are executed in a number of discreet stages - Prefetch, Decode, Address Generate, Execute, and Writeback. As the ALU finishes one stage for a given instruction, it moves on to the next stage and in so

RISC Vs CISC

What makes the performance of one processor different to the performance of another is its architecture. To the end user this architecture is most obvious in terms of the processor's instruction set. We can classify instruction sets used in modern processors into two broad categories - reduced instruction set or RISC architecture processors, and complex instruction set or CISC processors.

The most fundamental difference between these two categories lies in how and when they move operands into memory. A typical CISC processor will let the programmer specify multiple memory operands per instruction. The virtue of this is that there is a reduced need to use processor registers to store temporary values, and registers are the most precious asset in any processor. However, accessing two or three memory based operands per instruction adds considerably to the complexity of that part of the processor which coordinates execution of instructions, the control unit.

This complexity means that the control unit has to be microprogrammed, in other words it is a processor in its own right. The control unit executes a microcoded program which determines how the main processor executes instructions. This means, of course, that the control unit is extremely flexible - change the microcode and one can change the characteristics of the main processor. However, this flexibility is achieved at the expense of a lot of complex circuitry and a considerable reduction in performance.

RISC architecture processors do not include memory accesses in instructions which involve execution by the arithmetic logic unit or floating point unit. In other words, they do not access multiple memory based operands, they take their operands from registers only. Operands are moved between registers and memory by simple load and store instructions. This is far simpler to control and as a result RISC processors do not need the sophisticated microcoded control units found in CISC architecture systems. The result is an enormous reduction in circuit complexity, and a comparable increase in speed.

There are many other variations between CISC and RISC processors, thus most RISC processors use pipelining in order to execute more instructions in a given time by executing them concurrently. However, pipelining is no longer exclusively used in RISC processors. As we have seen it is a technique employed by the Pentium to increase execution speed.

RISC processor designers are now moving beyond the concept of pipelining, to a concept which has so far been confined to use on supercomputers, the superscalar processor. In such a processor (the IBM RISC system 6000 is an example) the pipeline is not subdivided, but duplicated. This means that each functional unit of the processor has its own pipeline and can operate independently of other units. This is a form of parallel processing which can give an enormous boost to performance.

The further development of both RISC and CISC architecture based processor chips is set to continue for many years. It is impossible to sit down and rationally say that one type of chip is better than the other. The truth is that each type of processor has its own particular merits in a particular application. Thus the highly successful British designed Acorn ARM chip, a RISC processor, was the perfect choice for the new Apple Newton, whereas the Pentium is the perfect choice for a top range PC.

doing makes way for the next instruction in the program seqence. It is a design which optimises processing speed and is called a pipeline, because of the way that instructions move through it.

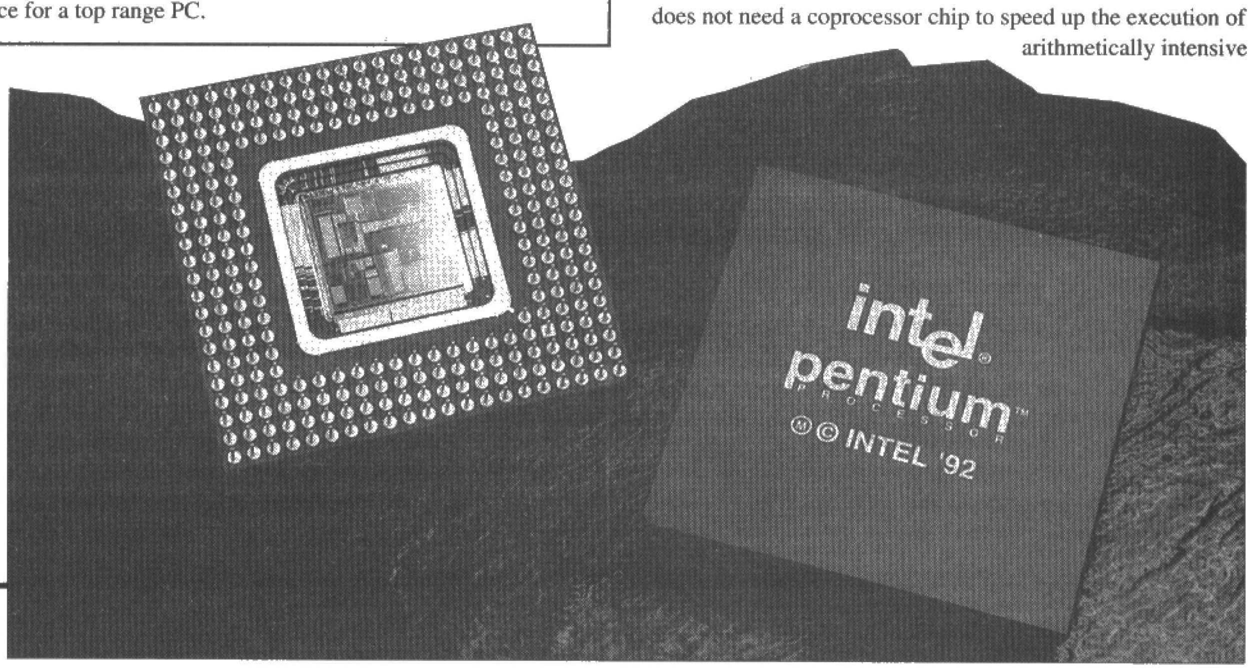
The fact that the Pentium design has two integer ALU pipelines means that it can, in the case of simple commands, execute two instructions at the same time, thus doubling program execution speed. The Pentium takes two instructions at a time and does an initial check to ensure that both are simple instructions, in other words ones where the result of one instruction is not necessary to the execution of the other. If both instructions meet this requirement then they are executed simultaneously. Otherwise only the first instruction of the two is executed in the U pipe ALU.

The fact that two instructions can be executed simultaneously means that there is a theoretical doubling of program execution speed, although in reality not all instructions are simple, so speed improvements are unlikely to ever approach the maximum. However, this feature does offer significant improvements in simple bit/byte manipulation, important in areas such as graphics.

Having two integer ALUs in the Pentium incurs the penalty of forcing the processor to make twice as many accesses to memory for instructions and data as would be necessary with just a single ALU. To overcome problems associated with this, Intel has had to split the 8Kb cache memory (see **What is Cache Memory**, for a description) used on the 80486 into two, so the Pentium has an 8Kb instruction cache and an 8Kb data cache. It was also found necessary to double the size of both the internal and external data busses to 64 bits, so that each time the Pentium accesses memory it brings in twice the number of instructions or bytes of data as does a comparable 486 memory access.

By splitting the cache into two, Intel has had to utilise some sophisticated techniques to ensure cache coherency between the instruction cache and the data cache. Without such techniques, a lot of problems can be encountered, in particular it makes it very difficult for programmers to use self modifying code.

The two ALU pipes are not absolutely identical. The U pipe includes a barrel shifter for bit level manipulations so that it can execute any 80 x 86 instruction, be it integer or floating point. In fact the U pipe ALU is the beginning of an eight stage pipelined Floating Point Unit, or FPU. The FPU is an extremely important component of the Pentium which, like the 486, does not need a coprocessor chip to speed up the execution of arithmetically intensive



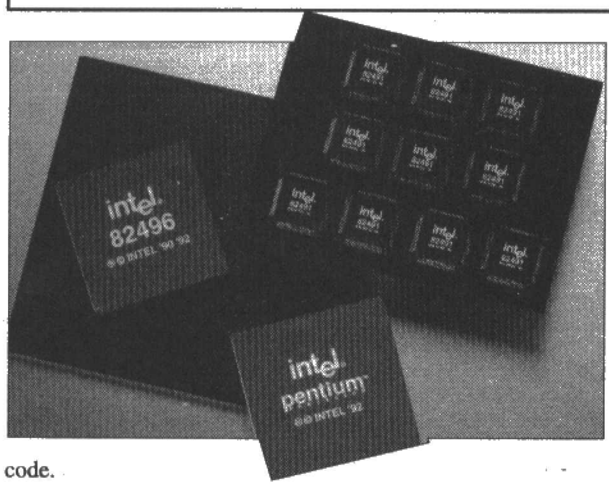
Pentium design constraints

The design of the Pentium posed an enormous number of problems, and integrating this chip into systems that will take full advantage of it, also looks beset with problems. The biggest headache facing engineers is designing a motherboard fast enough to keep up with the processor. Using the 50MHz 486DX processor has already stretched the capability of many designers, a 66MHz Pentium will cause even more problems, and a 100MHz version could well prove to beyond the capability of most designers.

Indeed, it has been said that the Pentium could mark the end for many clone manufacturers.

As designers move beyond 50MHz, there are an increasing number of considerations which need to be taken into account if a system is to run reliably. There are problems with thermal output, voltage variations, signal losses, RF interference, and TTL signalling. All these conditions become increasingly significant at high speeds and the margin for error becomes increasingly small. The thermal output of the Pentium alone is a significant factor, as it runs very hot and requires special cooling techniques. A simple fan is no longer enough and designers will have to use thermal modelling software to ensure correct heat dissipation and prevent local hot spots on a board.

Unless designers are very careful, the Pentium's high speed will lead to problems with bottlenecks, which will significantly degrade overall system performance. The data busses will not be fast enough, input/output circuitry will not be fast enough and memory will not be fast enough. To counteract these problems, designers will have to pull every known trick out of the bag. Solutions include much larger blocks of high speed cache memory, maybe as much as 512Kb, and the use of very high speed local bus based designs such as Intel's PCI bus (we will be examining bus systems in a future issue of ETI).



code.

In the past, the need for an arithmetic coprocessor was largely confined to a minority of PC users, users of programs such as AutoCAD where complex graphics images needed large numbers of equally complex mathematical calculations to generate the displays. Today, with the advent of multimedia, digital video and complex graphics creation and manipulation packages, the need to have a processor which can very rapidly handle floating point arithmetic is felt by the majority of PC users. Hence the integration of a sophisticated optimised FPU onto the Pentium chip.

Into the future

The above is just a brief look at how the Pentium processor chip works and how it represents quite a considerable change from earlier generations of Intel processors. It is still not a design which can be described as being at the leading edge of computer architecture, but because it will be the processing power behind the next generation of PCs it is an extremely important product. Upon it will depend the future of computing throughout the world during the next five years.

Of course, within the design department of Intel the Pentium is already considered obsolete. There will be a double speed version of the Pentium just as there is a double speed version of the 486, the 486DX2 - currently, at half the power, the most powerful processor in the Intel range next to the Pentium. Intel designers are also working on a new generation of processor due to make its debut in less than eighteen months and codenamed the P6, which will use over ten million transistors on one chip, and offer users over twice as much power as a standard Pentium.

It seems that we are still a long way from seeing an end to the further development of the 80 x 86 family of Intel processors which, for the next decade or more, will power the 50 million or so PCs that are sold every year throughout the world.

What is Cache Memory?

As processor chips get faster so they start to encounter one of the major bottlenecks in the design of a modern PC. This is the incompatibility in speed between the fast processor and the much slower memory chips. Processor instruction cycles are now considerably shorter than the access time of the average memory chip.

The solution to this problem has been to use a small intermediary block of memory with very fast access times, fast enough not to slow down the processor. This block of fast RAM is called the cache and is used to store frequently needed information. On a processor chip like the Pentium there are two 8Kb blocks of cache memory actually on the processor chip.

When the processor requests a block of program code or data from memory, the processor will invariably have to wait for the memory to deliver the required information. A copy of this block of information will, however, be stored in cache memory. This means that if the same block of instructions or data is accessed again, then there will be no need for the processor to wait, since it will be accessible from the fast cache memory rather than the slow main memory.

The cache memory on the main processor chip can also be augmented by external or secondary cache memory. This again acts as in intermediary between main memory and processor cache, and consists of very fast RAM chips. Most modern PC designs have room on their motherboards for such external cache memory, indeed some Pentium designs will support up to 512Kb of external cache. Cache memory is also added to video and disk controllers to speed up their performance.

The use of cache memory is a very important tool in the system designers' armoury. It can significantly improve performance, with gains of between 20 and 100 per cent compared with non-cached designs.

Electronics and the disabled

How electronics can be used to help disabled people live fuller lives

There are over six million adults in the UK who are classified as having one or more disabilities. That means over six million people who are unable to live their lives to the full, for some reason or other. They might be blind, or deaf, unable to walk or move and yet be as mentally alert and able as any non-disabled person. For such people life can be a long sequence of frustrating experiences and unfulfilled desires.

However, we can do something to help such people, we can use the technology that has been developed to give them back some of the freedom which the rest of us take for granted. Freedom which means that the disabled can do things without having to rely on the help of others. Freedom to take up a job and with it the independence, the self respect, and the social interaction with other people that comes from working for a living.

We have all seen and admired the way in which the renowned physicist Dr Stephen Hawking has overcome his disabilities with the aid of a computer and speech synthesiser to continue working, writing and lecturing in different venues across the world. Without that technology he would be denied the freedom to continue working and we would be denied access to his intellect and genius.

The kind of technology which has been applied to assist Professor Hawking could equally well be applied to helping a great many of the 6 million disabled people in this country. It can be used within limits to let the blind read, let the deaf hear, let the dumb speak and the physically disabled move. The technology to do this is neither particularly complex, nor particularly expensive, but with the exception of hearing aids, such technology is, by and large, not available commercially. Unfortunately, disabled people and their families cannot walk into Dixons and buy such systems, neither can they get the NHS to provide it.

One reason why electronic systems aimed at helping the disabled are not considered to be potential commercial products is that every disability, indeed every disabled individual, has their own special requirements. Thus, although there may be six million disabled people in the country, with the exception of those who are either deaf or blind, only a few thousand of them may share exactly the same requirement. The result is that devices designed to help the disabled are invariably tailored to the requirements of the individual. In consequence commercial devices are very expensive, hence the reason why they are not available on the NHS.

This is an area wherein the electronics hobbyist can help by building and designing such systems. We have the technology and, as individuals knowledgeable about electronics, we are in an ideal position to apply that technology. In this way we can help disabled friends, relatives and individuals in our local community to lead fuller and more productive lives.

Types of system

Most disabled people share one problem in common, difficulties in communications with people and everyday things which all of us take for granted at home and at work. A blind person cannot read an ordinary book or newspaper, watch the television or use a computer screen. Someone who is deaf or dumb cannot use the telephone, or hold a verbal conversation with someone. Those who are motor-disabled (unable to use one or all of their limbs) may be able to see, hear, and speak, but they might find it impossible to perform simple actions like switching on a light, writing a letter, or using a computer keyboard.

Improving communications is therefore the key to helping most people who have a physical disability. For all but the most profoundly deaf, hearing aids can be used to amplify sound and thus make best use of what hearing capability there is. For the blind, texts in Braille, and more recently Braille reading machines, have made reading possible. For other forms of disability we can use technology, in particular the personal computer coupled with appropriate electronic circuitry, to improve communications in many different ways.

As an example we can use a voice synthesiser connected to a PC to give someone with speech problems, caused by something like cerebral palsy, the ability to communicate verbally and make use of the phone. Similarly, a single switch system and some electronics can allow a quadriplegic capable of just minimal head movements, to use a PC to write letters, dial up friends on the phone, switch lights and other electrical devices off and on, and in general control the world around the individual.

It is the latter application which we will be looking at in the project part of this article. In future months we will be looking at a number of other systems which can be constructed at minimal cost to help disabled people. We will be looking at speech synthesisers, at voice input, and remote actuators.

Project description

This is a very basic system designed to help individuals with severe physical disability, for example someone who is completely paralysed as the result of an accident, or someone suffering from a muscular disease. Such individuals may well be capable of a very small amount of movement, slight hand pressure, or head movement, but are unable to manage a conventional keyboard.

What this project does is to combine a simple interface circuit with a computer program to create a system whereby a single microswitch can be used to replace a conventional keyboard. A microswitch which can be closed with a very small amount of pressure and is therefore an acceptable input device for someone with this type of severe physical disability.

The project is intended for a conventional PC with a parallel I/O board that is based around the 8255 PPI chip. The parallel I/O board project in this issue is suitable, as is Maplin's Programmable PC I/O Card (available from Maplin as a kit, price £21.95).

The output from the 8255 PPI consists of three eight bit bidirectional I/O ports. This project uses all eight lines of port C as output and one line from port A as input. The input is to the microswitch, and the eight output lines are used to control a number of relays that can be used to control other low voltage, low current equipment, such as a transistor radio or a torch type reading lamp. Turning mains equipment off and on requires much more sophisticated circuitry and involves associated safety problems.

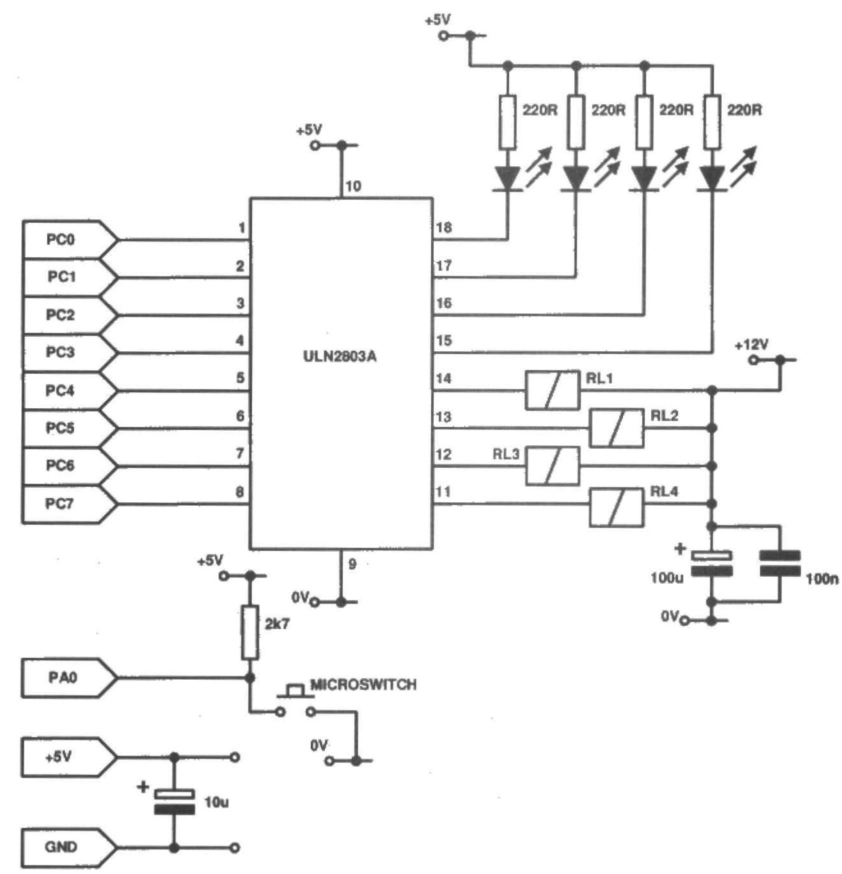


Fig.1. Circuit diagram for single switch control keyboard

Circuit description

The circuitry for this simple version of a single switch keyboard is shown in Figure 1. It can be divided into two parts, the microswitch circuit and the relay circuit with its associated indicator LEDs.

The microswitch circuit is very simple. It is connected to line 0 of port A on the 8255 PPI. When the microswitch is open, the normal condition, this line is held high by being connected to the +5V supply obtained from the PC I/O card. The microswitch itself is connected between line 0 and ground, so that when closed, it pulls the line low.

The relay and indicator circuit is more complex. This circuit allows for the attachment of four relays and four indicator LEDs. Since these devices all require a reasonable driving current they can not be attached directly to the 8255. The correct driver current is provided by an octal Darlington driver chip, the ULN2803A, the inputs to this chip being connected directly to the eight lines of port C on the 8255, and the outputs to four LEDs and four relays.

The LEDs, the common miniature red variety, are connected between the top four ULN2803A output lines and the +5V supply from the PC I/O card, each LED is connected in series with a 220ohm resistor to ensure the correct drive current. The four relays are sub-miniature types, the FM91Y from Maplin,

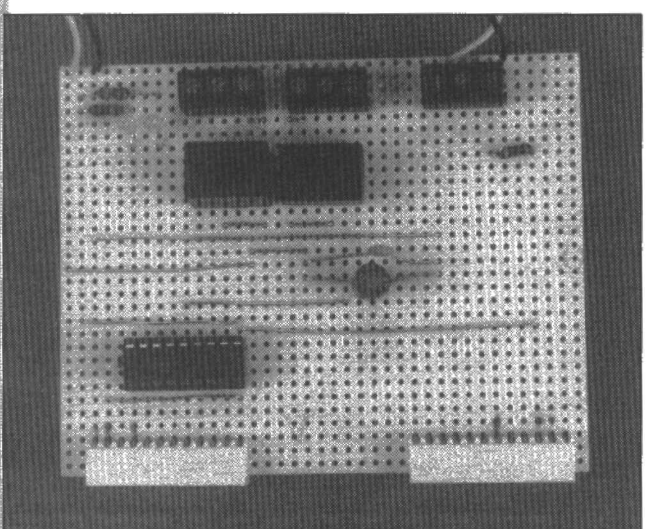
which require a power supply of 12V for the relay coil. This is provided by a 12V battery. Note that the battery ground is connected to the ground from the PC and to pin 9 of the ULN2803A.

Project construction

This is a simple demonstration system and, because every system will have different requirements, it is not really practical to design a printed circuit board for it. Consequently, it was constructed using Veroboard, as shown in the accompanying photograph.

A ribbon cable was used to attach the circuitry to the PC I/O board. At one end was a 40 pin D Type connector which plugged into the I/O board and, at the other end, three ten pin PCB connectors which were attached to the cable via a piece of 39 strip Veroboard, so as to provide a motherboard into which a variety of different boards could be plugged if required (see photo).

The main circuit was built on a piece of 100 x 100mm 0.1 pitch Veroboard, with two ten-way plugs to fit the appropriate pins on the motherboard soldered to one end. Three three-way screw terminals are soldered at the other end of the board (this example circuit only uses two relays) for attaching the microswitch cable and cables to devices to be controlled by the relays. Board layout is very simple and for the reasons given above is not shown.



The microswitch is a simple normally open type. How this switch is actually used depends upon the disability of the user. It could be mounted within a simple hand grip made from foam rubber, so that a very small amount of hand pressure would close the contacts, or the body of the switch could be mounted to some rigid structure and an arm connected to the lever so that contacts could be closed by a small amount of head movement. Conversely, other types of microswitch could be used, such as the pressure sensor switches used in some washing machines. These could be activated with a suck/blow type system. This is an area where inventiveness is essential.

The relays in this example can be used to control any low voltage, low current device. Thus, one could modify a portable transistor radio to allow it to be turned on and off simply by cutting the positive voltage battery lead and connecting the two ends via the relay. The relay can then act as an on/off switch. Similarly the 12V battery used to power the relay coils could also be used to power a small torch type reading/night light. Again this is an area where inventiveness is called for.

Turning mains devices off and on is a lot harder and should only be attempted by those readers with experience in this area. To protect both the user and the computer, opto-isolation should be employed wherever mains devices are controlled by a computer.

The computer program

This simple circuit is controlled via the PC I/O board by a program running on the PC. Included in this article is an example program, written in Microsoft QBASIC and showing the fundamental control principles (with minor modifications, this program should work with all versions of BASIC).

As can be seen from the accompanying screen shot, the program displays a keyboard on the screen as eight rows of thirteen characters, words or commands. A cursor consisting of three asterisks moves up and down the left most column, underlining each character/word/command in turn. This cursor remains on each row for a short period, the duration of which is determined by the delay loop in line 436. Before moving to the next row the program checks the status of the microswitch. If it is still open then the program moves the cursor to the next row. If the current row is the last, then the cursor jumps back to row 1.

If the microswitch is closed, then program control jumps to a section of code which moves the cursor along the selected row. Once again there is a delay between moving the cursor from column to column and the microswitch status is scanned. If the switch is found to have been opened again then the appropriate character/word is displayed, or the appropriate command executed. Otherwise the cursor will simply rotate back and forth along the row.

Since this is a demonstration program the commands incorporated into it are all very simple, things like delete the last character, or send the line of text to an attached printer. There is also a single CTRL command which can be used to turn a single relay and associated LED indicator either off or on. It functions simply as a toggle switch. The specified relay is attached to pin 12 of the ULN2803A and the associated LED to pin 16. They are turned on with the command line:

```
OUT IOREGADD%+2,34
```

and off by:

```
OUT IOREGADD%+2,0
```

The variable CTRL contains the current relay status that allows it to be toggled on and off.

This is a simple programme which is primarily designed to demonstrate the principles of a single key keyboard and device controller. It can be improved and expanded enormously to incorporate all sorts of different functions and can be made a lot more robust - a user will be most unhappy if the program crashes and leaves the system inoperative. Like the circuitry, the program is an area where the designer/developer can profitably use a lot of ingenuity.

Getting it together

This project has not been designed and is certainly not intended to be something built and created in isolation. It is intended to be used in a practical manner to help disabled people. Readers who are interested in taking up this type of project should contact local organisations which are set up to help the disabled. Also try contacting your local hospital or GP (though

```
_A_  _B_  _C_  _D_  _E_  _F_  _G_  _H_  _I_  _J_  _K_  _L_  _M_

_N_  _O_  _P_  _Q_  _R_  _S_  _T_  _U_  _V_  _W_  _X_  _Y_  _Z_

_a_  _b_  _c_  _d_  _e_  _f_  _g_  _h_  _i_  _j_  _k_  _l_  _m_

_n_  _o_  _p_  _q_  _r_  _s_  _t_  _u_  _v_  _w_  _x_  _y_  _z_
***
_._  _,_  _;_  _:_  _?_  _!_  _(_  _)_  _*_  _$_  _'_  _%_  _#_

_0_  _1_  _2_  _3_  _4_  _5_  _6_  _7_  _8_  _9_  _+_  _-_  _=_

_the__an_ _and__or_ _but__for__to_ _from_by_ _with_he_ _she__it_

_spc__rtn__prt__del__end__    __CTRL_   __   __   ___   __   __
```

please remember that these are very busy people, an initial written approach is probably best), as well as local representatives of national charities.

Readers who do develop applications, or are working on designs may well find it useful to talk to each other. Here, use of the ETI conference on CIX can be a great help, otherwise write in to ETI and we will do our best to put readers in touch with each other. We will also be running more projects of this type over the coming months. If you have done something in this area, let us know, we might well be interested in publishing details.

Nick Hampshire

Set-up Variables

Lines 10-87 define the variables used by the programme. Line 12 contains a single line of blank spaces for text deletion. Lines 41 and 50 set up the I/O board at address $300 hex so that Port A is defined as input and Port C as output. Lines 70-87 contain the data array used to set up the keyboard.

Display Screen

This simply takes the data stored in array A$(8,13) and places each character/word/command at the correct position on the screen.

```
10 REM initialise variables
11 REM there are 79 spaces between the quotes on the next line
12 SPC$ = "                                                                               "
15 CHANGE = 1
20 ROW = 1
25 COL = 1
30 COL = 1
35 CHARCOUNT = 1
36 LNE = 1
38 CTRL = 0
40 REM set up I/O board registers
41 IOREGADD% = &H300
50 OUT IOREGADD% + 3, 144
60 REM set up data arrays
61 DIM A$(8, 13)
65 DIM TEXT$(5)
70 A$(1, 1) = "A": A$(1, 2) = "B": A$(1, 3) = "C": A$(1, 4) = "D": A$(1, 5) = "E": A$(1, 6) = "F": A$(1, 7)
= "G": A$(1, 8) = "H": A$(1, 9) = "I": A$(1, 10) = "J": A$(1, 11) = "K": A$(1, 12) = "L": A$(1, 13) = "M"
80 A$(2, 1) = "N": A$(2, 2) = "O": A$(2, 3) = "P": A$(2, 4) = "Q": A$(2, 5) = "R": A$(2, 6) = "S": A$(2, 7)
= "T": A$(2, 8) = "U": A$(2, 9) = "V": A$(2, 10) = "W": A$(2, 11) = "X": A$(2, 12) = "Y": A$(2, 13) = "Z"
82 A$(3, 1) = "a": A$(3, 2) = "b": A$(3, 3) = "c": A$(3, 4) = "d": A$(3, 5) = "e": A$(3, 6) = "f": A$(3, 7)
= "g": A$(3, 8) = "h": A$(3, 9) = "i": A$(3, 10) = "j": A$(3, 11) = "k": A$(3, 12) = "l": A$(3, 13) = "m"
83 A$(4, 1) = "n": A$(4, 2) = "o": A$(4, 3) = "p": A$(4, 4) = "q": A$(4, 5) = "r": A$(4, 6) = "s": A$(4, 7)
= "t": A$(4, 8) = "u": A$(4, 9) = "v": A$(4, 10) = "w": A$(4, 11) = "x": A$(4, 12) = "y": A$(4, 13) = "z"
84 A$(5, 1) = ".": A$(5, 2) = ",": A$(5, 3) = ";": A$(5, 4) = ":": A$(5, 5) = "?": A$(5, 6) = "!": A$(5, 7)
= "(": A$(5, 8) = ")": A$(5, 9) = "*": A$(5, 10) = "$": A$(5, 11) = "'": A$(5, 12) = "%": A$(5, 13) = "#"
85 A$(6, 1) = "0": A$(6, 2) = "1": A$(6, 3) = "2": A$(6, 4) = "3": A$(6, 5) = "4": A$(6, 6) = "5": A$(6, 7)
= "6": A$(6, 8) = "7": A$(6, 9) = "8": A$(6, 10) = "9": A$(6, 11) = "+": A$(6, 12) = "-": A$(6, 13) = "="
86 A$(7, 1) = "the": A$(7, 2) = "an": A$(7, 3) = "and": A$(7, 4) = "or": A$(7, 5) = "but": A$(7, 6) =
"for": A$(7, 7) = "to": A$(7, 8) = "from": A$(7, 9) = "by": A$(7, 10) = "with": A$(7, 11) = "he": A$(7, 12)
= "she": A$(7, 13) = "it"
87 A$(8, 1) = "spc": A$(8, 2) = "rtn": A$(8, 3) = "prt": A$(8, 4) = "del": A$(8, 5) = "end": A$(8, 6) = "
": A$(8, 7) = "CTRL": A$(8, 8) = "   ": A$(8, 9) = "   ": A$(8, 10) = "   "
99 REM 3 spaces between the quotes above
100 REM main calling routine
110 GOSUB 200
115 COL = 1
116 ROW = 1
117 CHANGE = 1
120 GOSUB 400
125 CHANGE = SWSTAT%
130 GOSUB 600
140 GOSUB 800
150 GOTO 115
199 REM
200 REM display screen
201 REM
205 CLS
210 FOR X = 1 TO 8
220 FOR Q = 1 TO 13
230 LOCATE X * 2, Q * 5
235 REM 2 spaces
240 PRINT "_"; A$(X, Q); "_  ";
250 NEXT Q
260 NEXT X
290 RETURN
399 REM
```

```
400 REM vertical cursor movement
401 REM
420 FOR ROW = 1 TO 8
425 V = (ROW * 2) + 1
426 H = COL * 5
430 LOCATE V, H
435 PRINT "****"
436 FOR Q = 1 TO 200
440 GOSUB 1000
450 IF SWSTAT%  CHANGE THEN RETURN
456 NEXT Q
470 LOCATE V, H
475 REM 4 spaces
480 PRINT "    "
520 NEXT ROW
530 GOTO 420
599 REM
600 REM horizontal cursor
601 REM
620 FOR COL = 1 TO 13
625 V = (ROW * 2) + 1
626 H = COL * 5
630 LOCATE V, H
635 REM 2 spaces after the *'s
640 PRINT "****  "
645 FOR Q = 1 TO 200
650 GOSUB 1000
660 IF SWSTAT%  CHANGE GOTO 740
666 NEXT Q
670 LOCATE V, H
675 REM 4 spaces between the quotes
680 PRINT "    "
720 NEXT COL
730 GOTO 620
740 LOCATE V, H
745 REM 5 spaces between the quotes
750 PRINT "     "
760 RETURN
799 REM
800 REM character input
801 REM
810 CHARCOUNT = LEN(TEXT$(LNE))
815 IF CHARCOUNT > 75 THEN GOSUB 880
830 LOCATE LNE + 18, 1
835 X$ = A$(ROW, COL)
840 IF X$ = "spc" THEN X$ = " "
845 IF X$ = "rtn" THEN GOSUB 880: RETURN
850 IF X$ = "del" THEN TEXT$(LNE) = LEFT$(TEXT$(LNE), LEN(TEXT$(LNE)) - 1): GOTO 870
855 IF X$ = "prt" THEN GOSUB 900: RETURN
856 IF X$ = "end" THEN END
858 IF X$ = "CTRL" THEN GOSUB 950
860 TEXT$(LNE) = TEXT$(LNE) + X$
875 REM 3 spaces between the quotes
870 PRINT TEXT$(LNE); "   "
875 RETURN
880 REM carriage return line feed
881 LNE = LNE + 1
882 IF LNE > 5 THEN GOTO 888
883 LOCATE LNE + 18, 1
884 PRINT SPC$
886 RETURN
888 LOCATE 24, 1
890 PRINT "Print buffer full - print out"; : GOTO 906
900 REM print text
902 LOCATE 24, 1
903 REM 17 spaces after word text
904 PRINT "printing text                 ";
906 FOR Q = 1 TO 5
908 LPRINT TEXT$(Q)
910 TEXT$(Q) = ""
912 NEXT Q
914 LNE = 1
916 LOCATE 24, 1
918 PRINT SPC$;
920 LOCATE LNE + 18, 1
922 PRINT SPC$
930 RETURN
950 REM control routine
956 IF CTRL = 0 THEN CTRL = 1: GOTO 970
958 IF CTRL = 1 THEN CTRL = 0: GOTO 980
960 RETURN
970 REM turn device on
974 OUT IOREGADD% + 2, 40
976 X$ = ""
978 RETURN
980 REM turn device off
984 OUT IOREGADD% + 2, 0
986 X$ = ""
988 RETURN
999 REM
1000 REM switch input routine
1001 REM
1020 SWSTAT% = INP(IOREGADD%)
1030 SWSTAT% = SWSTAT% AND 1
1060 RETURN
```

Move Cursor

The code between lines 400 and 599 moves the cursor vertically. Between lines 600 and 799 horizontally. Delay loops in lines 436 and 645. Variables V and H determine the current vertical and horizontal cursor positions.

Input Character/Word/Command

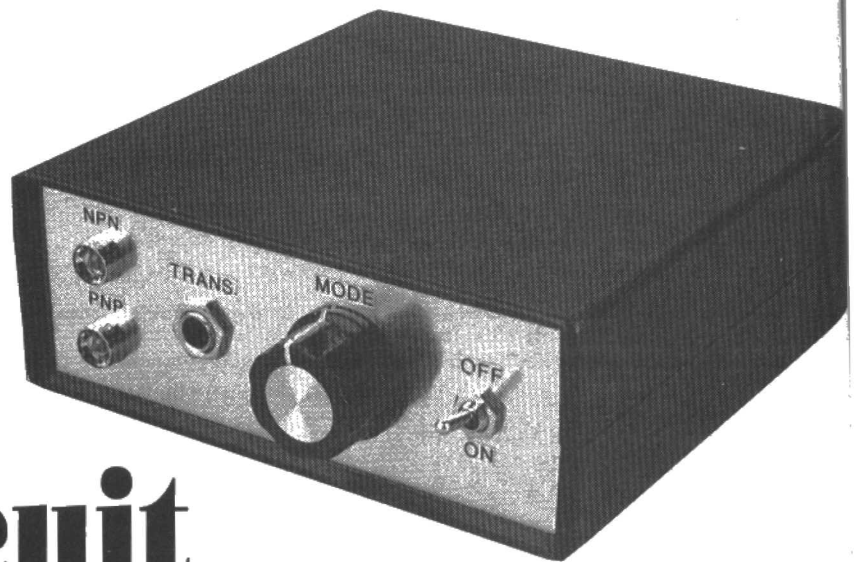
Selected characters/words are displayed at the bottom of the screen, a buffer allows up to five 75 character lines of text, when the buffer is full its contents are output to the attached printer. Lines 840-856 parse the string returned by the keyboard seletion code to check for commands.

Execute Commands

Lines 880 through to 999 contain a sequence of command execution routines.

Check For Switch Closure

The code between lines 1000 and 1060 look at line 0 of Port A on the 8255 PPI chip in the PC I/O card, and set the variable SWSTAT accordingly.



No need to unsolder components with Robert Penfold's in circuit transistor tester

In Circuit Transistor Tester

Transistor testers range from simple 'go - no go' checkers, through to comprehensive analysers. With discreet transistors being used to a much lesser degree these days, the cost of a complex transistor analyser is difficult to justify. For most purposes, a very simple and inexpensive checker of the type described here is perfectly adequate.

The unit can be used to check npn or pnp silicon transistors, which can be in or out of circuit at the time. A LED indicator flashes at a rate of a few Hz if a test device is serviceable. A test transistor has gone closed circuit if the LED switches on continuously, or open circuit if the LED fails to switch on at all.

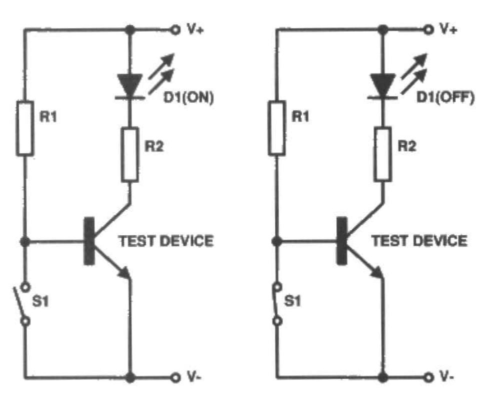


Fig.1(a) The test device is biased into conduction and D1 lights up.

Fig.1(b)The test device is switched off and D1 fails to light.

Tester Basics

A simple transistor checker can use the basic arrangement shown in Figure 1. Feeding a small current into the base terminal of a transistor causes a much larger current to flow in its collector circuit. In this case a LED indicator, D1, and a current limiting resistor, R2, act as the collector load for the test device. The latter is operated as a simple common emitter switch.

In Figure 1(a), the test transistor is biased into conduction by the base current received via R1. The value of R1 is chosen so that any transistor which has at least a moderate amount of gain will produce a strong enough collector current to light D1 at full intensity. In Figure 1(b), S1 short circuits the base and emitter terminals of the test device, which ensures that it receives no base current. Now, only minute leakage currents flow to the collector circuit, and D1 fails to light up. In a real transistor checker circuit, S1 is an electronic switch that is controlled by a low frequency oscillator. The LED indicator should flash in sympathy with S1 as it switches on and off.

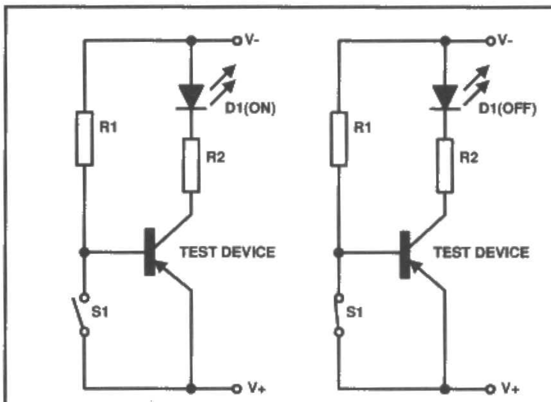


Fig.2 The pnp equivalent to Fig.1. The polarity of D1 and the supply have been reversed.

A faulty test component will produce something other than proper flashing from D1. Probably the most common fault is when a transistor has simply gone open circuit, and applying a base current does not produce a significant increase in the collector current. This fault condition is indicated by D1 failing to switch on at all. Sometimes a transistor that has been 'blown' exhibits a virtual short circuit between the base and collector terminals. This type of fault will be indicated by D1 simply switching on continuously. If the test component has a very low current gain, D1 will flash, but at low brightness.

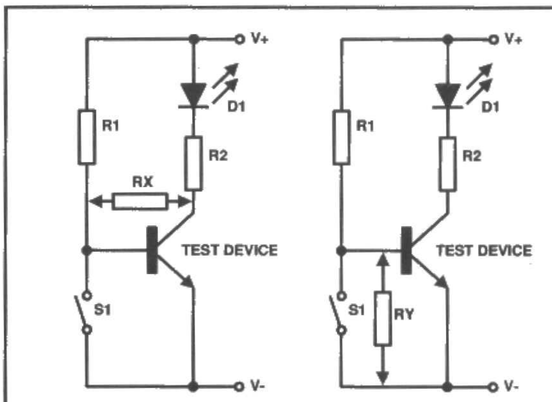


Fig.3 In-circuit resistances can affect results.

PROJECT

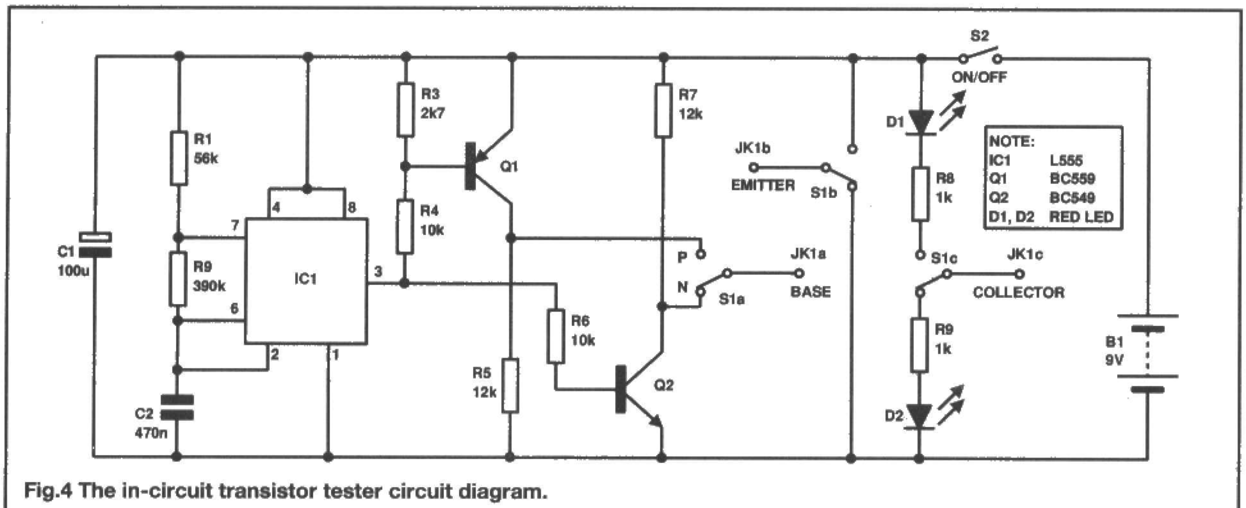


Fig.4 The in-circuit transistor tester circuit diagram.

However, if a supposedly high gain transistor actually exhibits a slightly inadequate but still quite healthy amount of current gain, D1 will flash properly. Subtle faults of this kind can only be detected using more sophisticated transistor testing equipment.

The test set-up of Figure 1 is only suitable for npn transistors. For checking pnp devices the slightly modified arrangement of Figure 2 is needed. The supply polarity has been reversed, which in turn necessitates a reversal in the polarity of D1. The circuit is otherwise the same as the original, and it operates in exactly the same way.

Testing transistors which are out of circuit is very straightforward, but there are potential problems when testing devices that are still fitted on a circuit board. There will inevitably be some resistances between the terminals of the test components. These resistances will be provided by the bias resistors, load resistors, etc. in the circuit.

There will often be some resistance across the base and emitter terminals of the test device, as in Figure 3(a). Sometimes this is provided by a bias resistor connected directly between the collector and base terminals. In other instances, this resistance will be present via a more circuitous route.

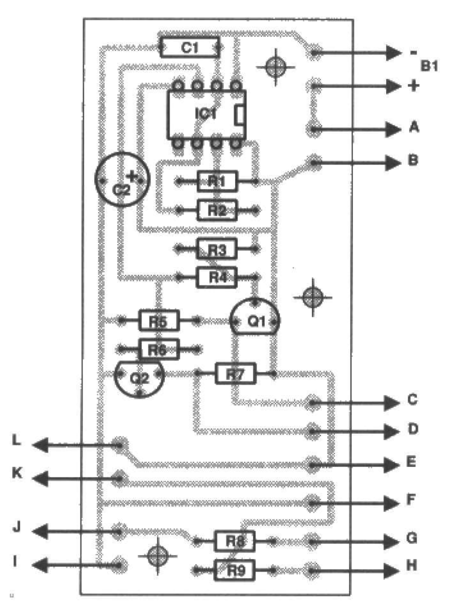


Fig.5 The transistor tester component overlay

Either way, this resistance has the potential to hold the test device in the 'on' state. It is for this reason that the base current is switched off by short circuiting the base and emitter terminals of the test component, rather than simply having the switch in series with R1. By short circuiting the base and emitter terminals, the test device will be switched off regardless of any in-circuit resistances.

Unfortunately, this does not entirely eliminate the problem, since the current flow through S1 and RX will result in D1 being forward biased. In practice this normally produces a current flow that is too low to produce more than a fairly dim glow from D1. However, if D1 does glow slightly during the 'off' half cycles, this is probably not indicative of a faulty device. In fact, this seems to occur in the majority of cases, but the glow from the LED in its 'off' state is usually so slight as to be barely noticeable.

In many circuits there will be a relatively low resistance across the base and emitter terminals of the test component, as in Figure 3(b). This can produce problems due to the potential divider action across R1 and in-circuit resistance RY. The resistance of R1 must be low enough to ensure that a potential of about 0.6V can be achieved at the base of the test device, or the test transistor will fail to switch on. On the other hand, R1 must be high enough in value to prevent D1 being switched on by test transistors which have extremely low current gains. The value of R1 therefore has to be something of a compromise.

Circuit Operation

The circuit diagram for the transistor checker appears in Figure 4. The low frequency oscillator is a standard 555 astable, based on IC1. An ordinary 555 can be used for IC1, but in the interest of good battery life it is better to use a low power type such as an L555, ICM7555 or TLC555CP. The output frequency of IC1 is about 2Hz, and the output waveform is something not far removed from a squarewave.

When S1 is set to the npn mode, TR2 acts as the electronic switch and R7 is the base bias resistor. D1 is the LED indicator and R8 is the current limiting resistor. With S1 set to the pnp mode, TR1 acts as the electronic switch while D2 and R9 act as the LED indicator and current limiting resistor. It would be possible to use the same LED for both modes, but using separate LEDs simplifies the npn/pnp switching, and makes it obvious if the unit is accidentally set to the wrong mode.

Provided that a low power version of the 555 is used for IC1, the standby current consumption of the circuit is only

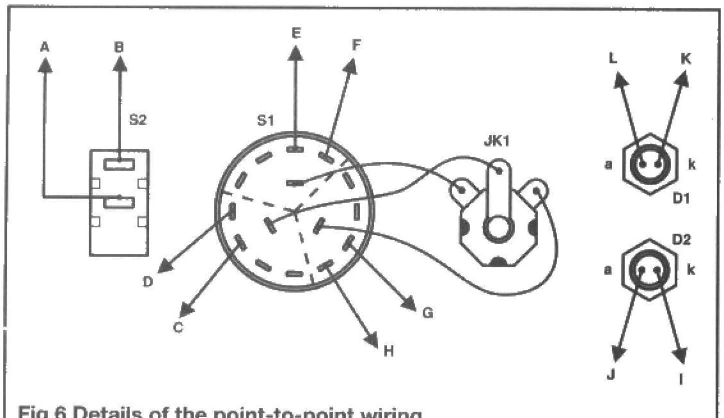
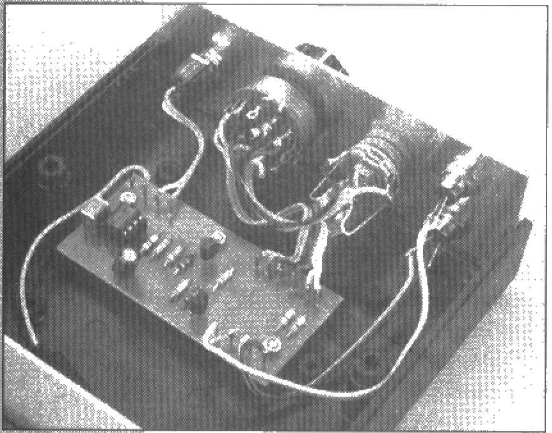


Fig.6 Details of the point-to-point wiring.

about 1.5mA. This rises to an average current consumption of approximately 6mA when one of the LEDs is flashing. A small (PP3 size) 9 volt battery is therefore adequate as the power source.

Construction

The transistor tester component overlay is shown in Figure 5. Construction of the board should present few problems. Although low power 555s are mostly based on CMOS technology, they have built-in protection circuits that render anti-static handling precautions unnecessary. It is still a good idea to use a holder for IC1, however. C2 must be a small radial type if it is to fit into the layout properly. Similarly, in order to fit into the layout correctly C1 must be a printed circuit mounting type, having 7.5mm (0.3in) lead spacing. Fit single sided pins to the board at the points where connections to off-board components will be made.



A plastic and metal instrument case measuring about 130 x 132 x 50mm is used as the housing for the prototype transistor checker. This case is somewhat larger than is really necessary and it should be possible to accommodate everything in practically any small project box. As the unit is operating at a very low frequency, the general layout is not critical. Any reasonably neat and sensible layout will do.

S1 is a standard 4 way, 3 pole rotary switch of the 'break before make' variety. Do not use a make before break switch. A switch of this type would briefly short circuit the supply each time it was operated. The adjustable end-stop of S1 is set for two way operation. Of course, any 2 way, 3 pole break before make switch can be used for S1. JK1 is a standard stereo jack socket of the open construction variety. Virtually any three way socket should be suitable.

The hard wiring is shown in Figure 6. This diagram should be used in conjunction with Figure 5 (e.g. point A in Figure 5 connects to point A in Figure 6). It is assumed, in Figure 6, that S1 is a 3 way, 4 pole rotary switch and that JK1 is a standard stereo jack socket. Be careful to connect everything correctly if you use a different type of switch or socket.

Pieces of multi-coloured ribbon cable are ideal for the point-to-point wiring, but ordinary multi-strand connecting wire can be used. The polarity of a LED is normally indicated by the cathode (k) leadout wire being slightly shorter than the anode (a) leadout wire. If necessary, the polarities of the LEDs can be found by trial and error. Connecting a LED the wrong way round will not cause any damage.

A set of test leads are needed. They consist of a standard stereo jack plug connected to three small crocodile clips via three pieces of ordinary multi-strand hook-up wire. Leads about 0.5m or so in length should suffice. The three leads should be different colours, so that the base, emitter and collector test leads can be easily identified. Alternatively, use crocodile clips of three different colours. Figure 7 shows the connection carried by each tag of the stereo jack plug.

In Use

At switch-on neither of the LEDs should operate. With S1 at the npn setting (position one) connect the base and collector

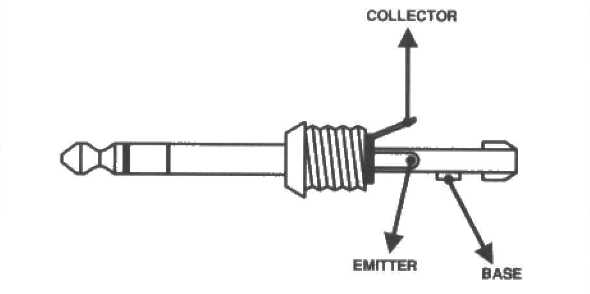


Fig.7 The stereo jack plug connects to test devices in the manner shown here.

test leads together. D1 should then flash at a rate of around two or three times per second. Set S1 to the pnp position and connect the base and collector test leads together again. This should result in D2 flashing at the same rate. Switch off at once and recheck all the wiring if the unit fails to respond properly.

When testing transistors out of circuit, start by connecting the emitter and collector terminals. This should produce only a minute current flow through the appropriate LED, which should not noticeably glow. If the LED glows slightly, this indicates a high level of leakage. This is quite normal for germanium devices, which makes testing them properly a difficult task. With modern silicon transistors a significant leakage level almost certainly indicates that the component is sub-standard. If the LED turns on continuously, the test device has gone closed circuit.

Connecting the base terminal as well should result in the appropriate LED indicator flashing brightly. The test device has gone open circuit if the LED fails to switch on at all. It is unlikely that the LED will flash at low brightness. However, if this should occur it indicates that the transistor under test has a very low level of current gain. In fact it has too little gain to be of any practical value.

Disconnecting the emitter terminal should result in the LED switching off and remaining switched off. There is a short circuit across the base and collector terminals of the test device if the LED still flashes with no connection to the emitter. This

indicates a serious fault, and means that the test component should be discarded.

The same basic techniques are used for in-circuit tests, but the possible effects of in-circuit resistances mean that results have to be interpreted more liberally. With only the emitter and collector terminals connected, a significant leakage level might be indicated. This could well be due to in-circuit resistances and does not necessarily indicate a faulty test component. With the base terminal connected as well, failure of the LED to flash could be due to low value bias resistors in the circuit. Look at the circuit diagram for the faulty equipment to see if there are any resistors which could be giving problems. Remember that inductors and transformers mostly have low resistances through their windings and are also a potential cause of problems. With low resistances across some of the test component's terminals, there is no option but to remove it from the circuit board prior to testing.

If a component under test gives the right responses, it is almost certainly fully operational. It is probably not worthwhile giving further checks to such a device unless desperation sets in! If a test device fails to give the right responses, then it should be removed from the circuit board so that it can be tested in isolation. A proportion of test components are likely to work properly once removed from the circuit board. In such cases the fault will normally be due to a faulty resistor or capacitor in the circuitry around the test device.

One final point is that testing power transistors using simple transistor checkers tends to be problematic. Power transistors are designed to provide good current gains at high collector currents and they are often inefficient when operated at low currents. This factor is compounded by the fact that most power types have relatively low current gains anyway. Most power transistors will actually give the right responses when used with this tester, even though it operates with a collector current of only about 7mA or so. However, if a power transistor produces slightly less than normal LED intensity, this does not necessarily mean that it is faulty.

R. Penfold

PARTS LIST

RESISTORS

R1	56k
R2	390k
R3	2k7
R4,6	10k
R5,7	10k
R8,9	1k

CAPACITORS

C1	100µ 10V radial elect
C2	470n polyester

SEMICONDUCTORS

IC1	L555 (see text)
TR1	BC559
TR2	BC549
D1,2	Red panel LED

MISCELLANEOUS

S1	4 way, 3 pole rotary (set for 2 way operation)
S2	SPST mini toggle
B1	9V (PP3 size)
JK1	Standard stereo jack socket

Case, control knob, battery clip, 8 pin dil IC holder, stereo jack plug and test leads.

Car Alarm

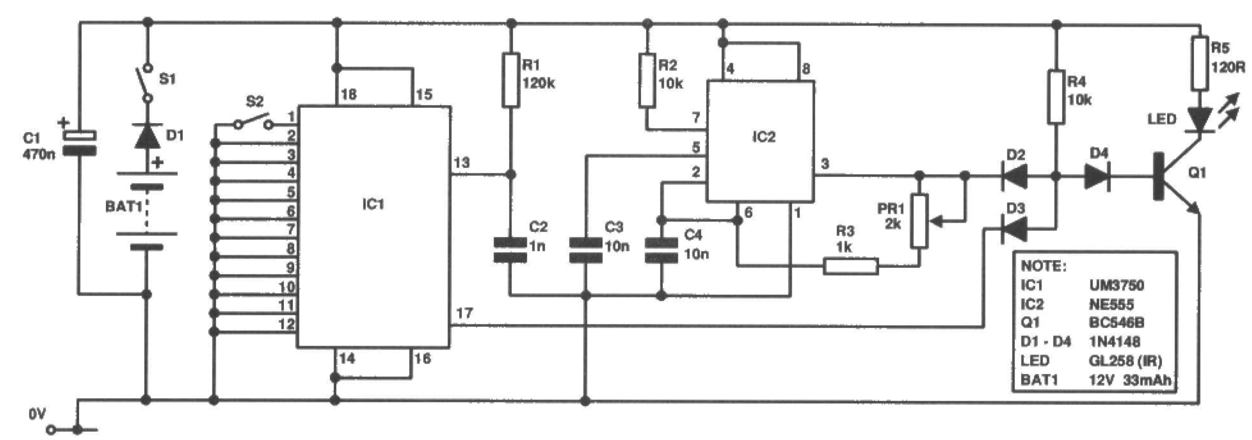


Fig. 1 Circuit diagram of alarm key

How It Works

Diode D1 is used for two things. When the maximum voltage on UM3750 is 11V, we can use the diode to drop the 12V supply voltage by 1V. It also protects the transmitter from wrong battery connection polarity. The UM3750 is very sensitive to wrong polarity.

Capacitor C1 is very important. It stablilises the supply voltage. If it is not used, then the burstwave would interfere with the UM3750s RC input and the transmitter would not work at all.

S1 is the transmit-button. It must be connected before the stabiliser capacitor as capacitors always leak current.

Finally there are D2, D3, D4, R4, T1, used as an AND-gate to feed burstwaves to the IR diode (LED1) when output is high on IC1. Figure 7. shows how the transmitter works.

Part two of our car alarm project deals with the transmitter

Last month we looked at the actual alarm circuit and how it is fitted into a car. In this issue we look at the remote control transmitter unit which is employed to activate and deactivate the alarm. It is no good having a burglar alarm if the alarm can not distinguish between the legitimate user and the burglar.

The transmitter is in fact an infra red remote control key, for turning the alarm off and on. As such it needs to be small and compact and this design utilises surface mounted components to achieve the required degree of miniaturisation.

Transmitter Design

When initially working on the design of this project, there was a choice of infra red or radio transmission between the portable key unit and the car mounted alarm, but a quick look at the problems involved quickly resolved the choice in favour of infra red. The reason was simply that even if radio transmission is preferred, it is hard to design, bulky and subject to many legal restrictions. Fortunately, an infra red based communication system is perfectly adequate. In virtually all lighting conditions one can achieve a transmission range of 10 metres or more.

The circuit diagram of the transmitter is shown in Figure 6.

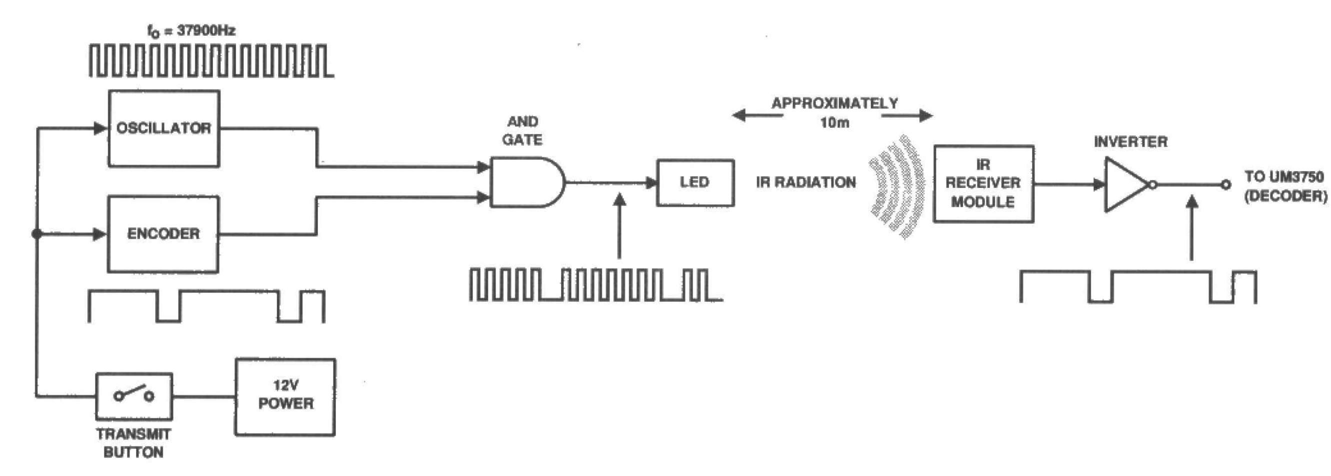


Fig. 2 Block diagram of Alarm key

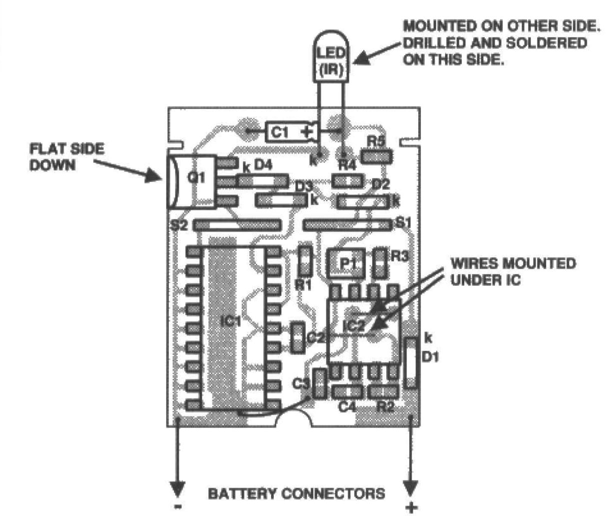


Fig. 3 Component overlay of alarm key

It consists of two integrated circuits. IC 2 is an old favourite which everyone will be familiar with, the NE555 coupled as an astable mulbrivator. This is used to provide a good 50% duty cycle burstwave in squarewaves, which is used to supply the IR diode.

At the heart of the transmitter is the 18-pin UM3750 encoder/decoder. The supply voltage for this chip has a wide tolerance and can be anywhere between 3V and 11V. In a portable unit, this is a very useful feature since it means that one does not have to frequently change batteries. The resistor and capacitor are connected to pin 13 which is the RC-oscillator input. These two components must have exactly the same values in both transmitter and receiver.

The HC-NE01 will only detect burstwaves at 37900Hz, this is designed to reduce interference between the infra-red transmission and daylight, light bulbs, etc. The NE555 oscillator is used to create a burstwave of this frequency. By turning the potentiometer P1 it is possible to tune the frequency very close to 37900. The more accurate the tuning, the greater the operating distance.

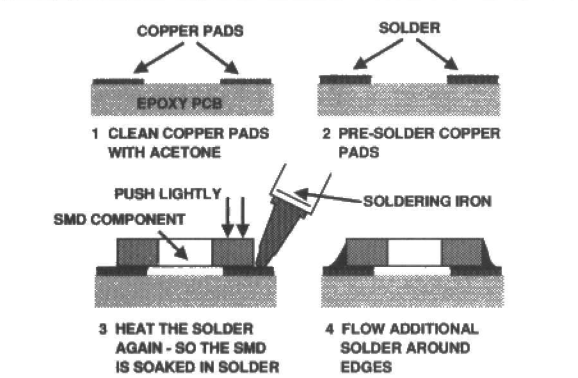


Fig. 4 How to solder surface mounted devices

Building the Transmitter

To build the transmitter, you need time, precision, and good tools. The hardest job is soldering all the SMD components. You need a clean soldering iron with a sharp edge. The PCB must be carefully cleaned and I found it easier to mount both ICs first, since the SMD components are weak.

But the first task is to set the identity code. Cut the same PCB tracks which connect pins 2-12 of the UM3750 that were cut when building the alarm circuit. Note that pin 1 is should be left uncut.

There are two wires under IC2, which must be mounted before the IC itself.

Bend the pins horizontally and cut them in half on both ICs. Make a solder blob on each copper connection on the PCB. Now, place the IC over the solder and warm them up again, so the pins are covered in solder. Start with pin 9 and 18 and then continue with the others. Do the same with IC 2.

Now, solder the SMD components, diodes, transistors and buttons in the same way as we did with the ICs. The battery connections can be harder and I had to solder them with a wire. Make sure you do not apply heat for too long to the battery.

Study the component overlay in figure 3.

Finally, drill a 5mm hole for the IR diode and mount it. Some modifications to the box might be necessary to make the PCB fit completely. Finish the project and fasten the ignition-key on the chain. The left button is only used to change the transmitted code, if you have two cars with this alarm system and different identity code. The right button is the 'transmit' button.

If it is working, adjust the potentiometer as close to 37900 Hz as possible, using an oscilloscope or frequency counter.

With both the transmitter and alarm circuits built and installed you can now hopefully look forward to reducing the potential for car crime in your own neighbourhood.

Magnus Pihl

PARTS LIST

The transmitter

RESISTORS

R1	120k, SMD 0.125W
R2,R4	10k, SMD 0.125W
R3	1k, SMD 0.125W
R5	120ohm, SMD 0.125W
P1	2k, linear, SMD

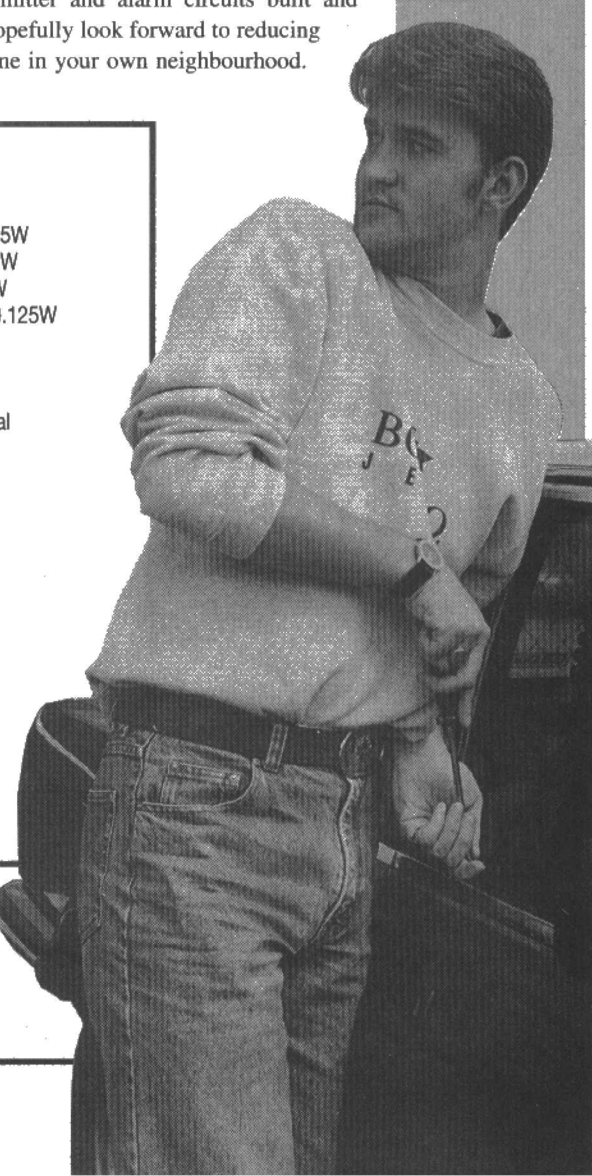
CAPACITORS

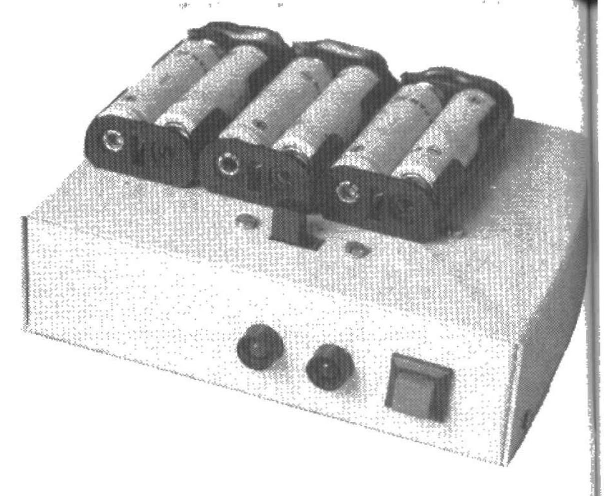
C1	0.47µF/16V, axial
C2	150pF, SMD
C3,C4	10nF, SMD

SEMICONDUCTORS

IC1	UM3750
IC2	NE555
T1	BC 546b
D1-4	1N4148
LED	GL528
E	12V battery (10.6 x 28.5mm)

See last month for details of reciever components





Rapid NiCd Battery Charger

Recharge AA size NiCd batteries with Terry Balbirnie's fast portable charger

This NiCd rapid charger has been designed to recharge ordinary AA NiCd cells in about one hour. It is designed to be portable and uses a 12V car supply instead of the mains. The unit can charge 2 or 4 cells at a time, with each having a capacity (energy content) of 500mAh. The higher capacity types provide 600 and 700mAh, but these will need to be charged for 72 and 84 minutes respectively.

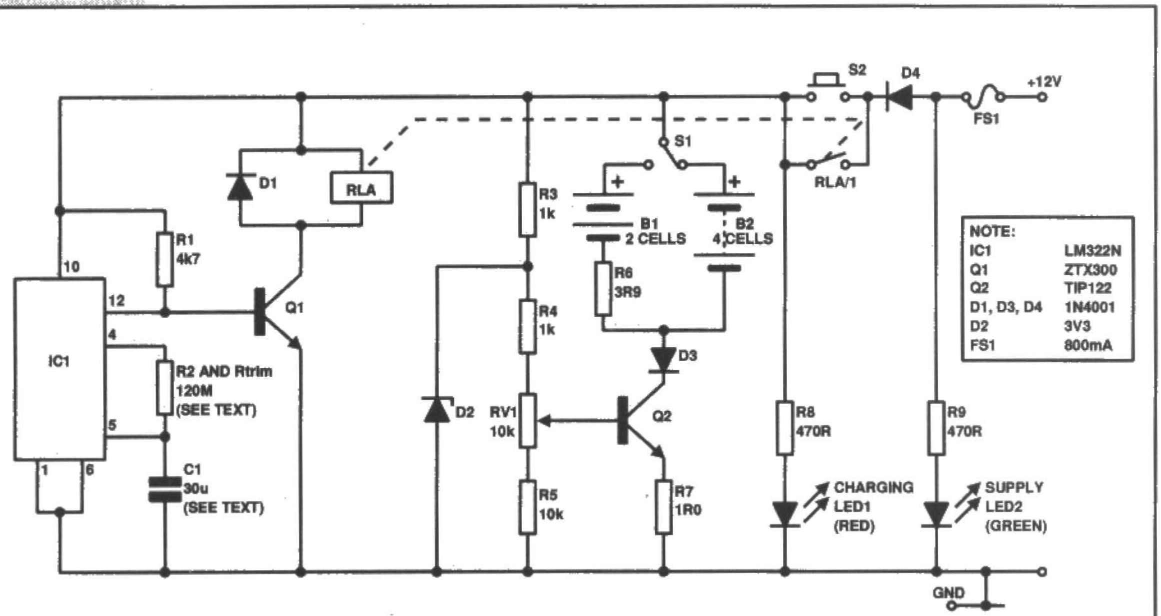


Fig. 1 Circuit diagram of fast battery charger

Charging AA size nickel-cadmium cells using a small current of, say, 50mA is easy. But shorter charging times are only possible through the use of a larger current. At 5A charging time is reduced to 9 minutes! However, ultra-rapid charging causes problems with overheating and short battery life. These problems are avoided by using a compromise of 750mA, the solution adopted in this design, although even at this rate care needs to be taken to avoid overcharging or the cells may be damaged. The NiCd Rapid Charger has been designed to meet all these requirements

Circuit Description

The complete circuit diagram is shown in Figure 1, and consists of two sections. The first forms the timing section, the second is responsible for current regulation.

The timing section is built around IC1. With a 12V dc supply connected to the unit, green LED2 operates through a current-limiting resistor, R9. Timing is initiated by pressing push button switch S2. Current then flows through fuse FS1 and diode D4 to IC1 pin 10. Current also flows through current-limiting resistor, R8, and operates red LED1, the charging indicator.

When power is applied to IC1 it begins a timing cycle. Pin 12 of IC1 is then virtually open-circuit and has no further effect. Current flows to the base of transistor, Q1, through current-limiting resistor, R1. This energises the coil of relay, RLA then makes (normally-open) contacts of RLA1 close and bypass switch S2. This switch need no longer be pressed since the relay contacts take over in directing current to IC1 and other parts of the circuit.

IC1 pin 4 provides an accurate reference voltage of 3.15V and capacitor, C1, charges up from this through resistor R2 (and Rtrim whose purpose will be explained later). This reference voltage is accurately maintained by on-chip circuitry throughout the timing cycle, to ensure that the capacitor charges at a precisely known rate, even when the supply voltage varies between wide limits. This means that, providing other components are of a sufficiently high quality, the time interval will be accurately pre-determined.

As C1 charges, the voltage across it, and therefore at pin 5,

PROJECT

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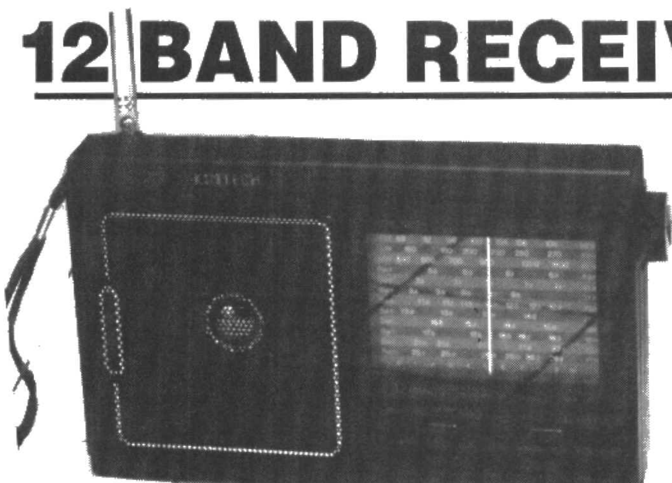

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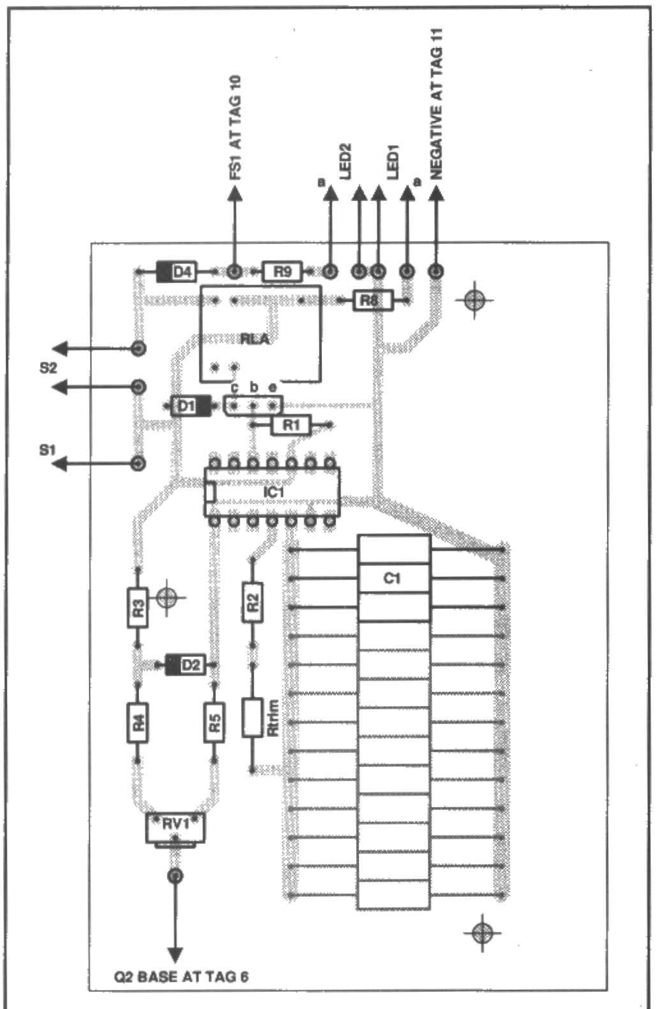


Fig. 2 Component overlay

rises. When this reaches exactly 2V, C1 discharges and the output transistor switches on, making pin 12 low. 2V is 63% of the reference voltage and the significance of this will be seen presently. With pin 12 low, Q1 base is made low also. The transistor therefore switches off and the coil of relay, RLA, is no longer maintained. The contacts now part and the entire circuit (apart from LED2) switches off. This marks the end of the timing cycle.

Diode, D1, bypasses the high voltage pulse which occurs when the magnetic field in the relay core collapses on switching off. Without this diode, other semiconductor components in the circuit could be damaged.

Timer IC1 is designed to end the cycle after a precise single time constant. This is given in seconds and may be found by multiplying together C1 (in Farads) by R2 + Rtrim (in ohms). This is the same time that it takes for capacitor, C1, to develop a voltage of 63% that of the reference voltage across it, hence the 2V figure mentioned previously.

Since a long timing period is needed in this circuit, it is necessary for both C1 and R2 + Rtrim to have unusually high values. The specified value of C1 is 30mF and of R2 + Rtrim, 120MW. The time constant is therefore 3600 seconds or 1 hour. Since component tolerances could cause this figure to deviate a little, some means of adjustment is needed. This is provided by using a 100MW main resistor (providing a nominal time constant of 3000 seconds or 50 minutes) for R2 and the necessary number (nominally two) 10MW subsidiary resistors (Rtrim) connected in series with it, to achieve a timing of one hour or as required.

It is essential to use the correct type of capacitor, or capacitors, for C1, otherwise the timings may be erratic or the unit may not work at all. On no account use an electrolytic capacitor as they are subject to a high leakage current. Since it is being charged at an extremely low rate, it will self-discharge as quickly as it was charging and would thus never reach the 2V level. Even if it did, results would be unreliable.

While the circuit is timing and the relay contacts are made, current flows to the section of circuit centred on Darlington transistor, Q2, configured as a constant current source and working in the following way. The network consisting of R3 and Zener diode, D2 provides a constant 3.3V across D2. Resistors R4, RV1 and R5 form a potential divider connected across this 3.3V supply.

Preset potentiometer RV1 provides a range of voltage adjustment which the sliding contact applies to Q2 base. The effect is that a voltage appears across emitter resistor R7, which depends on RV1 adjustment. Since R7 has a fixed value, a certain current flows through it which depends only on the adjustment to RV1. This will be as predicted by Ohm's Law - I = V/R. At the end of construction, the preset will be set to provide an emitter current of 750mA.

The batteries on charge, B1 (2 cells) or B2 (4 cells) as selected by 2-way selector switch, S1, receive current from Q2 collector circuit, but since the collector current is virtually the same as that in the emitter, the cells will receive the correct charge rate.

Excess supply voltage over that required to charge the batteries and that appearing across R7 and D3, is developed between Q2 collector and emitter. When two cells are selected, some voltage will also exist across series resistor, R6. The purpose of this is to develop about the same voltage between Q2 collector and emitter, whether two or four cells are selected. If the charging current should begin to rise or fall for any reason, the transistor will compensate automatically and thus provide a reasonably constant charge rate throughout the timing cycle.

Diode D3 blocks any possible reverse flow of current from the charged batteries and so prevents them from discharging when the unit switches off. Diode D4 prevents damage, should the input lead be connected with the wrong polarity to the car system - that is, to the incorrect battery terminals. Fuse FS1 blows and prevents over-charging if more than 800mA flows due to a short circuit or other fault.

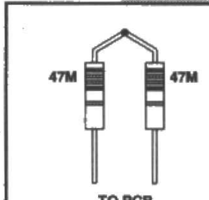


Fig. 3 Resistor R2

Construction

For accurate setting-up, you will need an ammeter (or multimeter) capable of reading up to 1A dc available at the end of construction. Apart from that, no specialised instruments are needed.

Since transistor Q2 becomes warm in operation, it is essential for the charger to be contained in an aluminium case with Q2 firmly secured to it, since the metalwork will act as a heat sink. Do not use a plastic enclosure.

Most of the components are mounted on a single-sided printed circuit board and certain high-power ones mounted off-board on a piece of tag strip. Begin with the circuit board. The relay is standard, having a 12V coil and 2A SPDT contacts. C1 (30mF) is difficult to source as a single component and R2

(100MW) may also cause problems. Plenty of space has therefore been left on the circuit board to accommodate multiple components to make up the values needed - more information about this is given presently.

The component side view of the PCB is shown in Figure 2. Prepare the circuit panel and drill the three mounting holes as indicated. Note the two rails labelled C1. Three 10mF capacitors may be connected in parallel here (i.e. across the rails) to give the correct value for C1. Three 33MW or two 47MW units connected together in series could replace the single 100MW resistor for R2 (see Fig. 3).

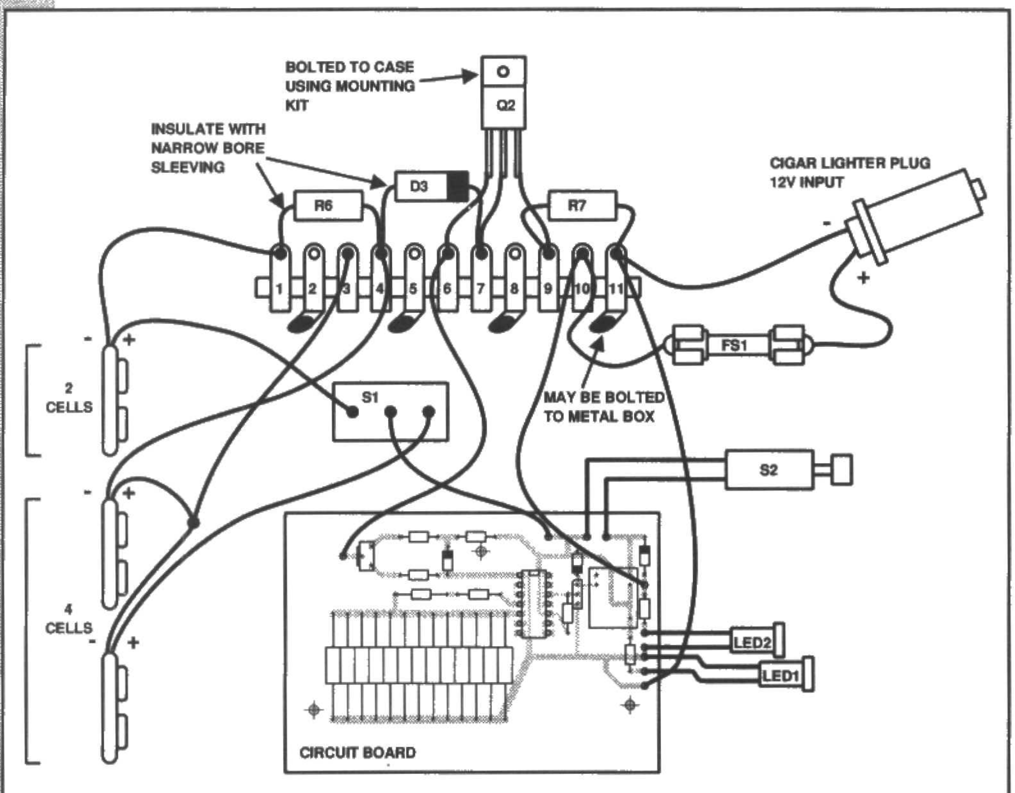


Fig. 4 Off board assembly

Solder all on-board components into position including IC1 socket but do not insert the IC itself until later, when assembly is complete and the board has been thoroughly checked for errors. Take care over the polarity of all diodes and of transistor, Q1.

The position marked Rtrim is temporarily linked with a short piece of connecting wire - this should be left slack so that later it may be cut through, and the trim resistor or resistors soldered between the new ends. The initial 100MW timing resistor is suitable for testing purposes.

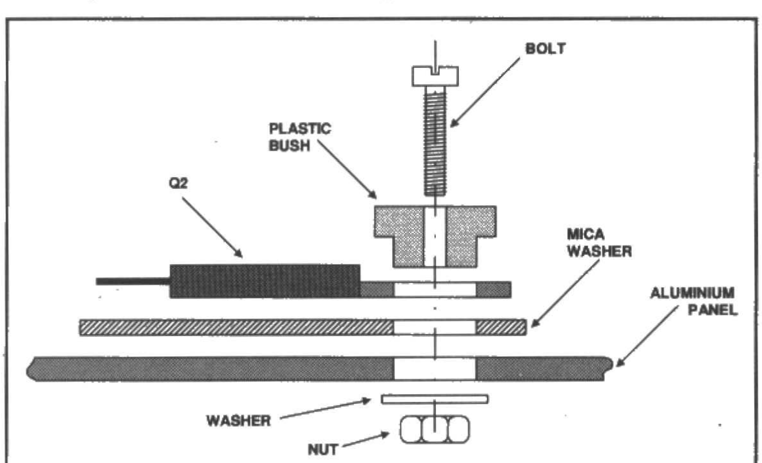


Fig. 5 TO220 insulating mounting kit

Connection from PCB to switches, etc., is via 15cm long pieces of light-duty multi-core connecting. Using different colours of wire will help to avoid errors which may be difficult to track down later. Insert IC1 into its socket, taking care over the orientation and the dangers of static. Finish by adjusting preset RV1 fully clockwise (as viewed from the left-hand edge of the circuit panel).

Next, prepare the off-board assembly. This uses a piece of tag strip and Figure 4 shows one possible arrangement using 11 solder tags. It is important that any tag which bolts directly to the metalwork, and thus to supply negative, must, with the exception of Tag 11, not be used for electrical connections. Place some narrow bore sleeving on diode D3 end leads to insulate them. Connect Q2 as shown so that it stands about 5cm (2 in) from the tag strip.

Prepare the case used to house the circuit panel and off-board components. The exact location of internal parts will depend to some extent on the size and shape of the enclosure being used. Think carefully before drilling holes to make sure that no short circuits will be caused between any components and the metal case when the lid is fitted. Drill holes in the base to correspond with those already made in the circuit board. Drill holes in the lid for the cell holders and one nearby for the connecting wires to pass through to components inside of the case.

Two-cell side-by-side battery holders are used and you will need three of these - two for four cells and one for two cells. Holders having PP3-type snap connectors were used in the prototype unit, but those having solder tags could also be used. The four-cell holder is made by connecting two 2-cell holders in series as shown. The common connection is soldered to the otherwise unused Tag 3 which keeps it out of the way and prevents short circuits. Of course, if you use a 4-cell holder, then the negative connection simply goes to Tag 4 and the positive one to the selector switch, S1.

Drill holes for switches S1 and S2, for fuse holder, FS1, LEDs and for entry of the input lead. Fit the supply input lead hole with a rubber grommet to prevent damage to the wire from the sharp edge of the hole. Also fit a grommet in the hole where the wires from the battery holders will pass through. Standard

LEDs may be attached with panel mounting clips or ready-made panel mounting LED indicators may be used as in the prototype - these improve the appearance of the finished project.

Mount the circuit board using short stand-off insulators on the bolt shanks to keep the underside at least 5mm clear of the metalwork. Drill holes and mount the tag strip. Mark the position of the hole in Q2 tab then remove the tag strip again. Drill the hole for Q2 and mount the tag strip. Q2 must now be attached using a TO220 insulating mounting kit. This consists of a thin mica washer, a plastic bush and a nut bolt and washer. This is used as shown in Figure 5.

The input lead consists of a suitable length of flexible twin wire. Fit the cigar lighter plug to one end. Then insert the fuse into its holder. Use a 1A fuse during testing since the current will probably rise above 800mA.

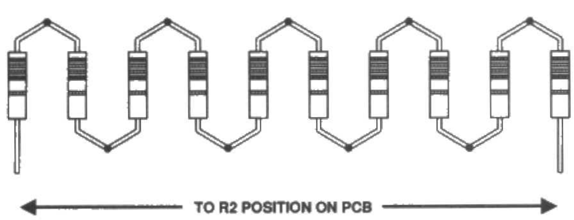


Fig. 6 Resistors R2 + RTRIM

Setting-up and Testing

In some cars, the cigar lighter circuit only operates when the keys are in the ignition - at the radio position. It is obviously a bad idea to leave keys in an unattended car. To avoid this, re-wire the lighter unit to a fuse of adequate rating which is live all the time.

The charger may now be adjusted for the correct timing and current output. Begin by measuring the operating time. No cells need be inserted, simply connect the unit to the cigar socket in the car - the green LED should operate - and press S2. The relay should click and the red LED should light and go off after about 50 minutes. Since 120MW (R2 + Rtrim) provides the correct timing, each 10MW is equivalent to five minutes approximately. To correct the timing, one or two 10MW resistors may then be connected in series in the Rtrim position. It is not necessary for timing to be exact - within five minutes is satisfactory.

When using higher powered 600mAh or 700mAh cells, a longer charging time is necessary, 72 and 84 minutes respectively. The nominal timing resistor values for these will be 144MW and 168MW.

Next, the operating current should be checked. To do this, insert two discharged cells in the appropriate holder and set S1 to the 2-cell position. Plug the unit into the supply and connect the cell holder in such a way that only the negative connection is made. Set the multitester to a dc current range covering 1A. Then put the negative test probe on to the free cell holder positive terminal and the positive one on the free connector terminal. The meter is thus connected in series with the cells on charge. Press S2 - the meter should give a very low reading or none at all.

Carefully adjust RV1 sliding contact anti-clockwise to give a meter reading of not less than 650mA and not more than 700mA. As Q2 warms up the value slowly creeps up by around 50mA, then rises very slowly or remains more-or-less stable. It is important that the current stays below 800mA throughout the timing cycle. Do a similar check using the four-cell pack, no change should be necessary. On completion of this test insert an 800mA fuse into the fuse holder.

Note that the green LED provides a fuse check - if it has blown, the LED will not light when the supply is connected.

All that remains is to assemble the case, although if the unit is to be operated in a cold damp environment it is a good idea to spray the PCB and off board components with a thin layer of water repellent silicone grease.

Terry Balbirnie

PARTS LIST

RESISTORS

R1	4.7k
R2/Rtrim	100M resistor or multiple resistors to make up near value, e.g. 2off 47M or 3off 33M, etc. - see text.
Additional 10M resistors for Rtrim - power rating unimportant.	
R3,R4	1k - 2 off
RV1	10k sub-miniature vertical preset.
R5	10k
R6	3R9 or 4R0 3W.
R7	1R0 3W.
R8,R9	470 - 2 off

All fixed resistors are 1/4W, 5% unless otherwise specified.

CAPACITORS

C1 30mF or multiple capacitors to make up near value, e.g. 3 off 10mF or 6 off 4.7mF miniature metallised polyester. 100VW (or any working voltage over 16V). See text.

SEMICONDUCTORS

IC1	LM322N precision timer.
Q1	ZTX300
Q2	TIP122 (or TIP120 or TIP121) power darlington.
D1,D3,D4	1N4001
D2	3.3V 400 or 500mW Zener diode.
LED1	5mm red light emitting diode and mounting clip
LED2	5mm green light emitting diode and mounting clip

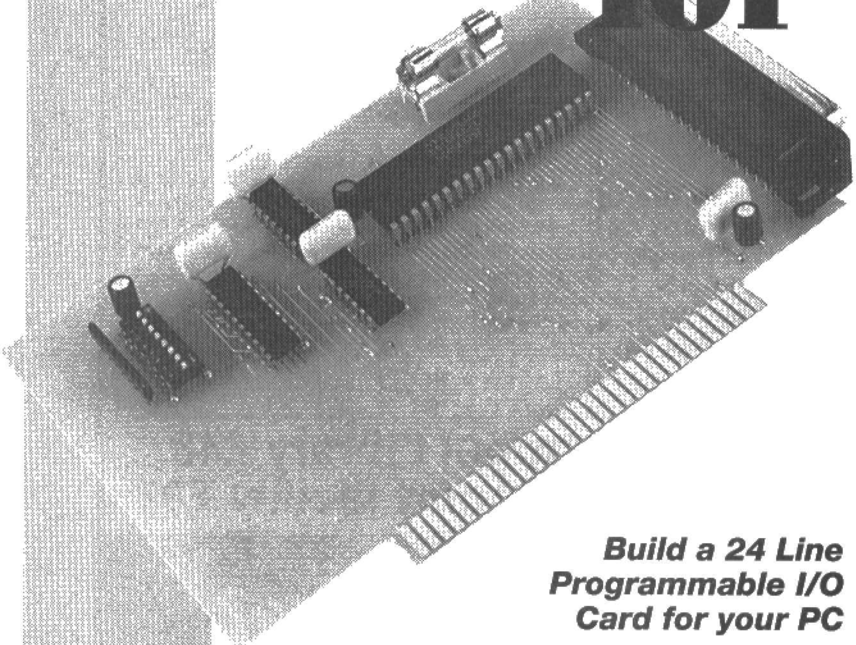
BUYLINES

Most of the components used in the NiCd Rapid Charger are readily available. IC1 - LM322N - is available from Farnell Electronics who can also supply 4.7mF metallised polyester capacitors for C1 (6 required) Order Code: 368 25475 and 33MW resistors for R2 (3 required) Order Code: V37 33M.
100MW Cermet film resistors for R2 are available from Electromail Order Code: 158-222. They can also supply 10mF metallised polyester capacitors (3 off required) Order Code: 113- 623
47MW resistors for R2 (2 off required) are available from Maplin as high voltage resistors. Order Code V47M. Maplin can supply the relay Order Code: YX 94C.

MISCELLANEOUS

RLA 12V miniature relay 300-400W coil and 2A SPDT contacts.
S1 SPDT rocker or toggle switch.
S2 SPST push to make switch.
FS1 20mm chassis fuse holder with 800mA quick-blow fuse to fit.
Additional 1A fuse advisable for testing purposes.
Printed circuit materials, aluminium case size 102 x 102 x 38mm.
3 AA size 2-cell holders or one 2-cell holder and one 4-cell holder - see text.
Tag strip (11 tags required), battery snaps for cell holders if required. TO220 mounting kit, 14-pin IC socket. Connecting wire, solder, rubber grommets, automotive cigar plug or ready-made automotive power lead, small fixings, etc.

A parallel port for your PC



Build a 24 Line Programmable I/O Card for your PC

Last month we looked at the design of a 24 line bi-directional parallel I/O interface board for the PC that was based upon the 8255PPI chip. This month we look at building, testing and using a board.

First let's review the circuit design. The circuit diagram is shown in Figure 1. It can be divided into two parts, to the right is the 8255PPI I/O chip and to the left is the address decoding circuitry which determines where the registers of the 8255 are located in the PC's I/O addressing space.

The address decoding is performed by the 74LS688, which is an eight line comparator. The I/O base address at which the board is located is set up using the eight switches in SW1. When one of these switches is open, then the line to the comparator is pulled high via the 10K resistor in RN1. When the

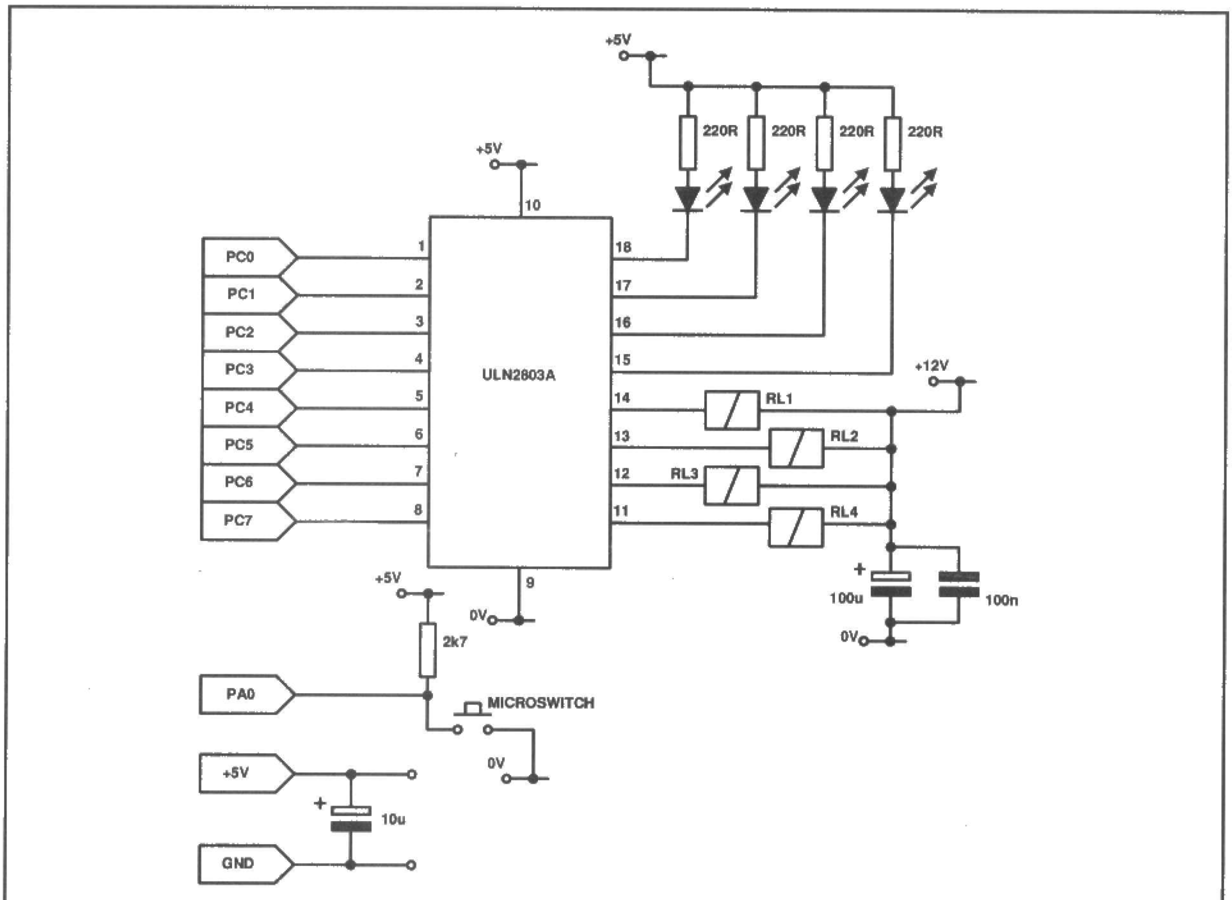


Fig.1. Circuit for PC parallel I/O port.

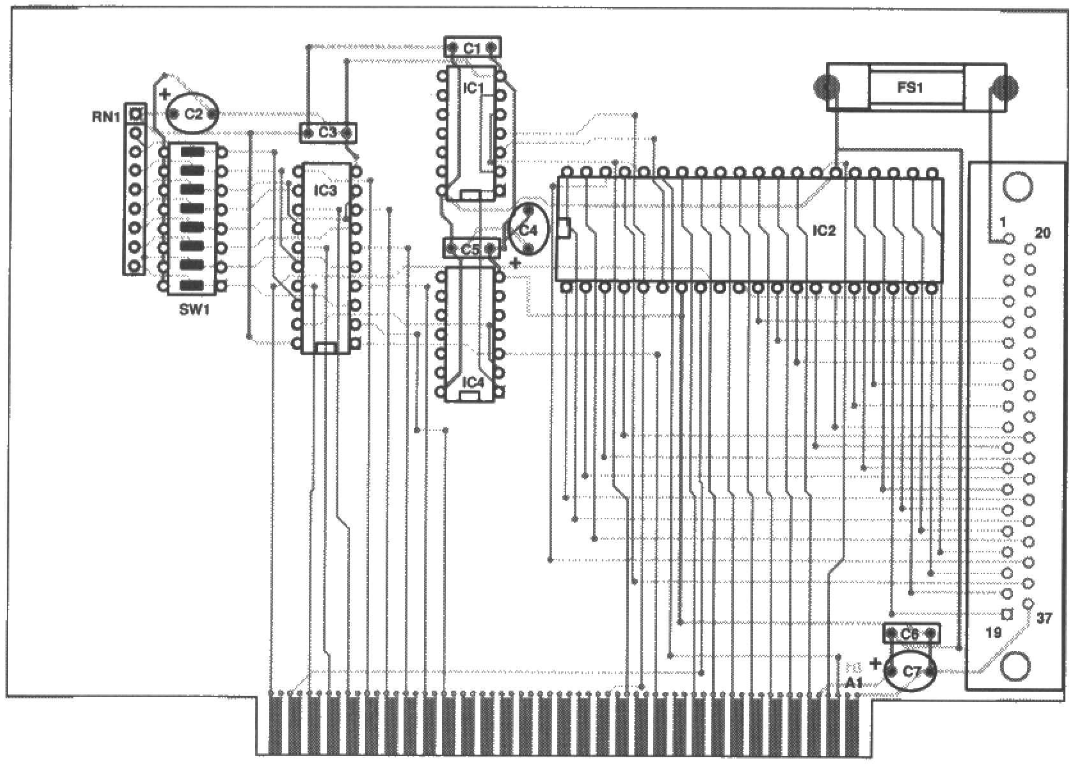


Fig.2. Board and component layout for PC parallel I/O port.

switch is closed, the line is pulled low. In this way a binary address can be set up using SW1 which is compared with the current address on the PC address bus. The four registers, memory locations to the PC, of the 8255 can be accessed by the PC only when the two base address values match.

The two NAND gates and the NOR gate are used to ensure that the 8255 is selected at the correct time, by combining the output from the address decode circuitry with state of three control lines from the PC bus.

Construction

The PCB board layout for this circuit is shown in Figure 2. Because the PCB used is not through hole plated, the first job is to connect all the vias on the board. Normally, pins would be used for this purpose but the track sizes are very small on this board and it is therefore necessary to use fine wire, stripped wire wrap wire is ideal, and solder to the tracks on both sides of the board.

This is a very tedious task, there are over fifty vias, but one which must be done with the utmost care. Joints should be checked visually, using a hand lens if necessary, to ensure that the joint has been made properly and that no solder has accidentally joined two tracks together. On many tracks, it is also possible to use a multimeter to check continuity.

Once all the vias have been soldered and checked, the other components can be attached to the board. Again, because this is not a through hole plated board, all components will have to be soldered on both sides of the board. A fiddly job, and one which must be done very carefully and thoroughly checked.

Unfortunately the need to solder components on both sides of the board makes it very difficult to use sockets for mounting the ICs. This means that ICs must be soldered directly to the board and very great care should be taken to ensure no damage to the chips from static discharge, especially when handling the 8255. This risk can be reduced by making sure that any static build up can be easily drained away to earth. One should also be extremely careful not to overheat any IC pins whilst soldering them, which again can damage the IC.

Testing

This is not an easy board to assemble and there are a lot of solder joints which must be very carefully checked before one should even consider plugging it into your PC. All joints should be visually checked, preferably with the aid of a hand lens. Then, using a multimeter, check the resistance between the +5V line and the 0V line on the PC edge connector, these are pins 29 and 31 respectively. The reading should be in the region of 1Kohm, much less than this and there is probably a short circuit on the board, which should be located and rectified before going any further.

Switch No	Address line	Binary value	Switch Setting
SW1	A9	1	ON
SW2	A8	1	ON
SW3	A7	0	OFF
SW4	A6	0	OFF
SW5	A5	0	OFF
SW6	A4	0	OFF
SW7	A3	0	OFF
SW8	A2	0	OFF

Table 1. Base address switch settings for 0300hex

Having checked the board for bad joints and shorts, the next step is to set the board base address. As mentioned last month, it is important to avoid using any base address which is being used by another board. Address 300hex is a good choice since this is reserved for use by prototype cards and it is unlikely that

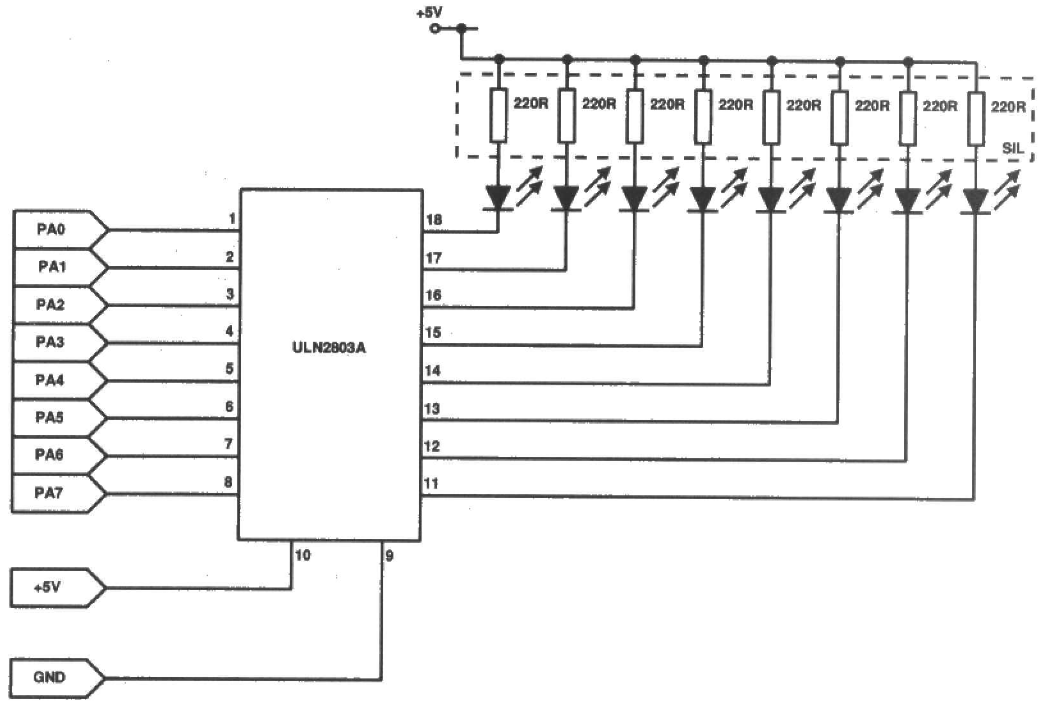


Fig.3. Test circuit for parallel I/O port

Description	Hex address PC/XT	Hex address PC/AT
Fixed disk	n/i	1F0-1F8
Games adapter	200-20F	200-207
Expansion unit	210-217	n/i
2nd parallel printer port	n/i	278-27F
Alternate EGA	2B0-2DF	2B0-2DF
GPIB (0)	2E1 *	2E1 *
Data acquisition (0)	2E2-2E3 *	2E2-2E3 *
Serial port 2	2F8-2FF	2F8-2FF
Prototype card	300-31F	300-31F
Fixed disk	320-32F	n/i
Network card	360-36F	360-36F
1st parallel printer port	378-37F	378-37F
SLDC	380-38F	380-38F
2nd Bisynchronous	n/i	380-38F
Cluster (0)	390-393 *	390-393 *
1st Bisynchronous	n/i	3A0-3AF
Monochrome adapter/printer	3B0-3BF	3B0-3BF
EGA	3C0-3CF	3C0-3CF
CGA	3D0-3DF	3D0-3DF
Floppy diskette controller	3F0-3F7	3F0-3F7
Serial port 1	3F8-3FF	3F8-3FF

n/i = not implemented

* = devices which decode the full 16 address bits and can thus reside in a range above 3FFhex. Thus, GPIB (1) resides at 22E1hex etc.

Table 2. IBM PC I/O Map

there will be any conflict. Table 1 shows how this I/O base address can be programmed into the eight switches of SW1.

The next procedure is to turn the power to the PC off, and unplug from the mains. The case can then be opened, or the cover removed and the board inserted gently and firmly into an empty expansion card slot, remembering to remove the expansion slot cover first. Then close the PC's case.

Only at this stage should power be supplied to the board by switching the PC on. However, there is very little that we can do to test the board as it stands, to properly test it we need a suitable test circuit. A circuit which simply consists of eight LEDs which can be turned off and on when attached to one of the eight line I/O ports of the 8255. This is shown in Figure 3 and can be easily assembled on a piece of Veroboard - see the accompanying photo.

The input lines of this test circuit, marked PA0 through PA7, should be attached via a length of ribbon cable and the 37 way D- type connector to the desired I/O port of the 8255. In this example these lines are connected to Port C. The +5V and Gnd lines to the test circuit should be obtained from lines 1 and 37 respectively of the D-type connector.

With the test circuit connected to the I/O board we can now test its functioning by running a simple program which switches the test circuit LEDs off and on. A sample test program written in BASIC is shown in Listing 1. It is designed to test Port C of the 8255 with a base address of 0300hex, by generating a sequence of binary values counting upwards from zero to 255, and then starting all over again.

If the board works properly then the LEDs should light in

the proper manner when the program is run. If they do not, then first check the base I/O address setting on SW1, double checking that there is no other board using the same address. If this fails, re-check all joints and components, double check component orientation, then re-run the test program.

Use

We covered programming the 8255PP1 chip in the last issue, but it is worth repeating some of the basics. The 8255 uses four I/O locations. Three of these are eight bit I/O registers and the fourth is a control register. So at the base address is the register for Port A, at base address+1, Port B, at base address+2, Port C, and at base address+3 the Control Register. We can use the computer to read data from, or write data to, any of the ports, but we can only write data to the control register.

It is the control register which determines how the 8255 functions. It determines the mode in which the chip will operate which in turn determines whether a particular I/O line functions as an input or an output line. The 24 I/O lines on the 8255 are grouped into three 8 bit ports, labelled A, B, and C, each of which corresponds to one of the 8255 I/O registers. However, the control register divides these 24 I/O lines into two 12 line groups, Group A and Group B. The lines in Group A consist of all the lines in Port A and the upper four lines of Port C. The lines of Group B consist of all the lines in Port B plus the lower four lines of Port C.

The control register features three operating modes for each of the two twelve line Groups of I/O lines. These modes are selectable by setting the appropriate bits within the control register and the function of each of the eight bits is shown in Table 2. Bit seven of the control register is the Mode/Bit Set/Reset bit, and is the key to programming the 8255. Normally this will be set to logic 1, where it allows Group A and B Modes to be selected, if set to logic 0 it will reset the 8255 registers.

In Mode 0 each of the 12 line Groups can be configured as a set of eight lines and as a set of four lines, which can be either inputs or outputs. In Mode 1 each Group of 12 lines can be configured to have 8 I/O lines, two handshaking lines and two further lines of I/O. Mode 2 governs all 24 I/O lines of the 8255, the Group A lines set up as a bi-directional bus with one line from Group B acting as a handshaking line, the remaining lines from Group B being configured to operate in either Mode 0 or 1. This should be made clearer by consulting Table 3.

Programming the 8255

If you can write a simple program in Basic you can program the 8255PP1. The key commands in GW or Q Basic are INP to input a value from an I/O address or OUT to output a value. The first thing to define in a Basic program which uses the 8255 is the base address at which the chip is located. So, at the beginning of the program, we need to have a line something like this:

10 BADR% = &H300

This sets up a variable called BADR which contains the base

```
10 BASEADD% = &H300
20 OUT BASEADD% + 3, 128
30 PRINT "INPUT NUMBER BETWEEN 1 AND 255"
40 INPUT Q
50 OUT BASEADD% + 2, Q
60 GOTO 30
```

D7		Mode selection
1		Mode Set
0		Bit Set/Reset
D6	D5	Mode selection - Group A
0	0	Mode 0
0	1	Mode 1
1	x	Mode 2
D4		Port A
0		Input
1		Output
D3		Port C (upper)
0		Input
1		Output
D2		Mode selection - Group B
0		Mode 0
1		Mode 1
D1		Port B
0		Input
1		Output
D0		Port C (lower)
0		Input
1		Output

Table 3. 8522 PPI chip Mode selection on the Control Register

address of the 8255 chip, in this case 0300hex. This variable can then be used when setting the Mode values and in all subsequent I/O operations to this chip. Thus, if we want to set up the chip so that the eight lines of Port A function as inputs, and the sixteen lines of Ports B and C function as outputs, then we would use the following line:

20 OUT BADR%+3,&H90

With these two lines executed we can write data to or read data from the three 8255 I/O Ports. So if we want to set all the output lines on Port B to logic 1 we would use the following command:

30 OUT BADR%+1,&HFF

and if we wanted to input state of the I/O lines on Port A into a variable called PORTA, we would use the following line:

40 PORTA% = INP(BADR%)

(For examples of programs which use an 8255PP1 based I/O card look at Listing 1 in this article and at the Program listing in the article on computing for the disabled.)

Connecting external circuitry

The I/O lines on the 8255PP1 chip are fully latched and buffered, but they are unable to source or sink large amounts of current. This means that, when configured as inputs, they are unable to accept voltages outside the range normally associated with 5V TTL and CMOS logic circuitry. Furthermore, when configured as an output, such lines are incapable of providing more power than is necessary to output data to one or two other TTL or CMOS chips.

It is very important that these limitations are born in mind because any attempts to exceed them will almost certainly lead to the destruction of your 8255, and may well lead to the

PARTS LIST

PC I/O Board

CAPACITORS

C1,3,5,7 100n monolithic
C2,4,6 10µ 16v electrolytic

RESISTORS

RN1 SIL pack 8 x 10K

SEMICONDUCTORS

IC1 74LS00
IC2 8255PP1
IC3 74LS688
IC4 74LS02

MISCELLANEOUS

SW1 8 x DIL switch
FS1 1A 22mm fuse and holder
37 way D-type connector socket right angled PCB type

Test Circuit

RESISTORS

R1 SIL pack 8 x 220ohm

SEMICONDUCTORS

IC1 ULN2803A
LED1-8 3mm red LEDs ordinary type

MISCELLANEOUS

Veroboard 2 x 1.5in
10 way ribbon cable
37 way D-type plug.

BUYLINES

This circuit uses widely available components. Those for the prototype were all obtained from Maplin.

destruction of your entire PC. So be warned!

The way around this problem is to provide a buffer, or perhaps even isolate, the inputs and outputs of the 8255 from any external circuitry. If the external circuitry is working using normal 5V TTL power, then buffering is probably adequate. At higher voltages, and particularly if switching mains voltages, isolation techniques are essential. We will be covering both of these subjects in the next issue.

Conclusion

An I/O board is a very useful add on for experimentally minded PC owners. With such a board installed in your machine you can start to explore the possibilities of using your computer to control and monitor a wide range of different types of external circuitry.

Readers who may find the construction of this project somewhat daunting should not despair. This board has been designed so that it is directly compatible with several other commercial I/O boards which are based upon the 8255PP1 chip, in particular Maplin's Programmable PC I/O Card.

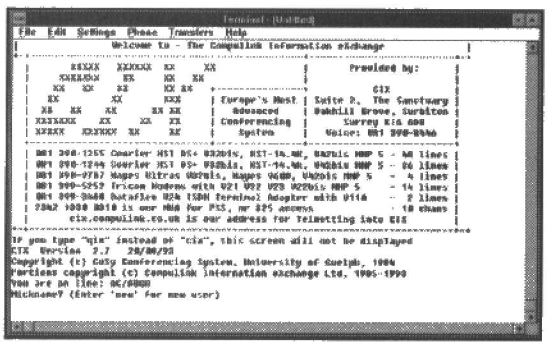
If you do build this board, then we will, over the coming months, be publishing a selection of useful and interesting projects based on it. Have fun!

Jim Morton

High technology communications for ETI readers

With ETI's new computer conferencing system, readers will be able to access a world of information and talk directly to other readers

Without a doubt, on-line computer services accessed via a personal computer, phone line and modem, are the communications and information medium of the future. They can be used to keep people in touch with the latest technical developments. They can be used to access an infinite quantity and wealth of information stored in computers all around the world. They can be used to communicate with like minded individuals anywhere on the globe, enlist their help in solving problems, searching for unusual items, or just simply having a chat.



ETI Online

With this in mind, we are instituting an on-line conference system for use by ETI readers. This conference will allow readers to exchange information and ideas, advertise surplus components, or download public domain and shareware programs. Readers will also be able to access information from around the world, send electronic mail to any one of over five million people, and even access the computers at NASA to get pictures of Mars or the current weather satellite image of Antarctica.

The ETI conference is being run on the computers of the Compulink Information Exchange, better known to many computer users as CIX. Anyone can join CIX, with a one off registration fee of £25 and hourly line usage charges of between £2.40 and £3.60 per hour. These will be directly debited to your credit card. The equipment needed to access CIX is a personal computer, which could be a PC, a Macintosh, an Amiga, Archimedes or an Atari, etc., a suitable modem operating at between 300 and 9600 baud and an appropriate communications program.

So what exactly is an on-line computer conference? It is basically a way in which users can hold conversations without being constrained by time or distance, both factors which restrict 'real-world' conferences. Thus, with a system like CIX, a user can log on to the conference at any time of night or day and from anywhere in the world, and add to the ongoing discussion. You can discuss matters of interest with people who you may not meet in your day to day work, you can trade information and opinions on your areas of expertise. Many people use CIX to obtain technical support, the wealth of information available from other users is phenomenal. You will often find your questions answered in full within minutes of putting them on the conference.

Users of a system like CIX can also use it to send and receive messages, using what is known as electronic mail, or E-mail. Using E-mail is simple, you have within the CIX com-

Communications software

Before one can use the modem to access an on-line system it is necessary to have a communications program of some sort running on your computer. There are a large number of such programs available, some freely available in the public domain, some sold commercially and others integral parts of other packages, such as the rather basic communications facilities offered by Windows.

Joining CIX

Joining CIX is very simple. Connect your computer and modem to the phone line, run your comms package and then dial one of the CIX phone numbers. These are 081 390 1255 and 081 390 1244

Once you have connected you should type CIX at the login: prompt. You will then be given a login banner with the CIX telephone numbers and address. At the next prompt, Nickname (or NEW for new user): enter nickname @cr:and finally at the Password: prompt, enter your password@cr>.

If you are new to CIX you should type CIX at the Login: prompt. You will then see the CIX login banner displaying the telephone numbers and address of CIX. At the prompt Nickname (or new for new user): enter new@cr>. You will then be taken through the on-line registration, where you will be given a nickname and password and asked for your name, address and credit card details. Shortly after registering, you will receive a registration pack in the post.

Because of a special deal between ETI and CIX, readers will not have to pay the usual £25 registration fee. In order to ensure that you are not charged, please make sure that CIX are aware that you are a reader of Electronics Today International and that you are applying for the discount when. registering

Any readers with further queries about CIX should telephone them on 0492 641 961.

puter an in 'basket' and an out 'basket' in which mail sent to you or by you is put. Unlike the conference system, where messages are public and can be read by any other conference user, the messages sent by E-mail are private and are sent to a specific user.

Every user on CIX has a mailbox and every user has a unique user ID, so sending a message is simply a matter of addressing it to a box with the appropriate user ID. You can also send E-mail to millions of people around the world using CIX's direct link to the world-wide Internet system. With E-mail, a message can be sent and received in seconds and often for less than the cost of a stamp (this is because in most cases, you only pay local phone charges rather than international ones). Furthermore, if the person you want to send it to is not on E-mail, then CIX will allow you to send a Fax just as easily.

Users can also use CIX to directly access information. There are over 50 gigabytes of disk storage for files on CIX alone, but if you really want to access information, then one should use CIX to access Internet, which gives access to thousands of computers around the world. Computers in companies, research institutions, universities and government departments. Computers from which one can access a vast array of resources, including databases, file servers, multi-user games, chat systems, satellite photos, etc. There is also a whole range of news services available through Usenet, which cover all sorts of different subjects. In fact, you name it and you will probably find it on Internet.

Now you know all about CIX, why not join and participate in the ETI on-line conference.

Modem selection

The key hardware component needed for accessing a system like CIX is a modem. This is a device which is used to convert the digital signals used by a computer to the analogue signals used by phone systems (the name modem stands for MODulator/dEModulator).

PC modems, particularly card modems for mounting inside your PC, are quite cheap and the widely available Amstrad modem card which works at 2400baud (baud = bits transmitted per second) can be bought for under £70, which is ideal for accessing something like CIX. The biggest problem facing anyone buying a modem is the enormous range of different communications standards which are now in use, and thus whether the modem you are buying will work with the on-line system you are thinking of using. A common specification from an on-line service for modems attached to it might read 'full duplex, compatible with V.21, V.22, V22bis, MNP5', which sounds very confusing.

The specification of 'full duplex' refers to the modem's ability to transmit and receive data concurrently. The numbers prefixed by a V refer to CCITT communications standards, while MNP5 is a data compression technique. The following are some of the more common specifications:

V.21 - 300baud duplex modem
V.22 - 1200baud modem
V.22bis - 2400baud modem with error correction
V.32 - 9600/4800baud full duplex modem
V.32bis - 14400baud full duplex modem
V.42bis - error correction and data compression which can be used to produce effective data transmission rates of up to 38.4Kbaud.
MNP5 - data compression technique developed by Microcom

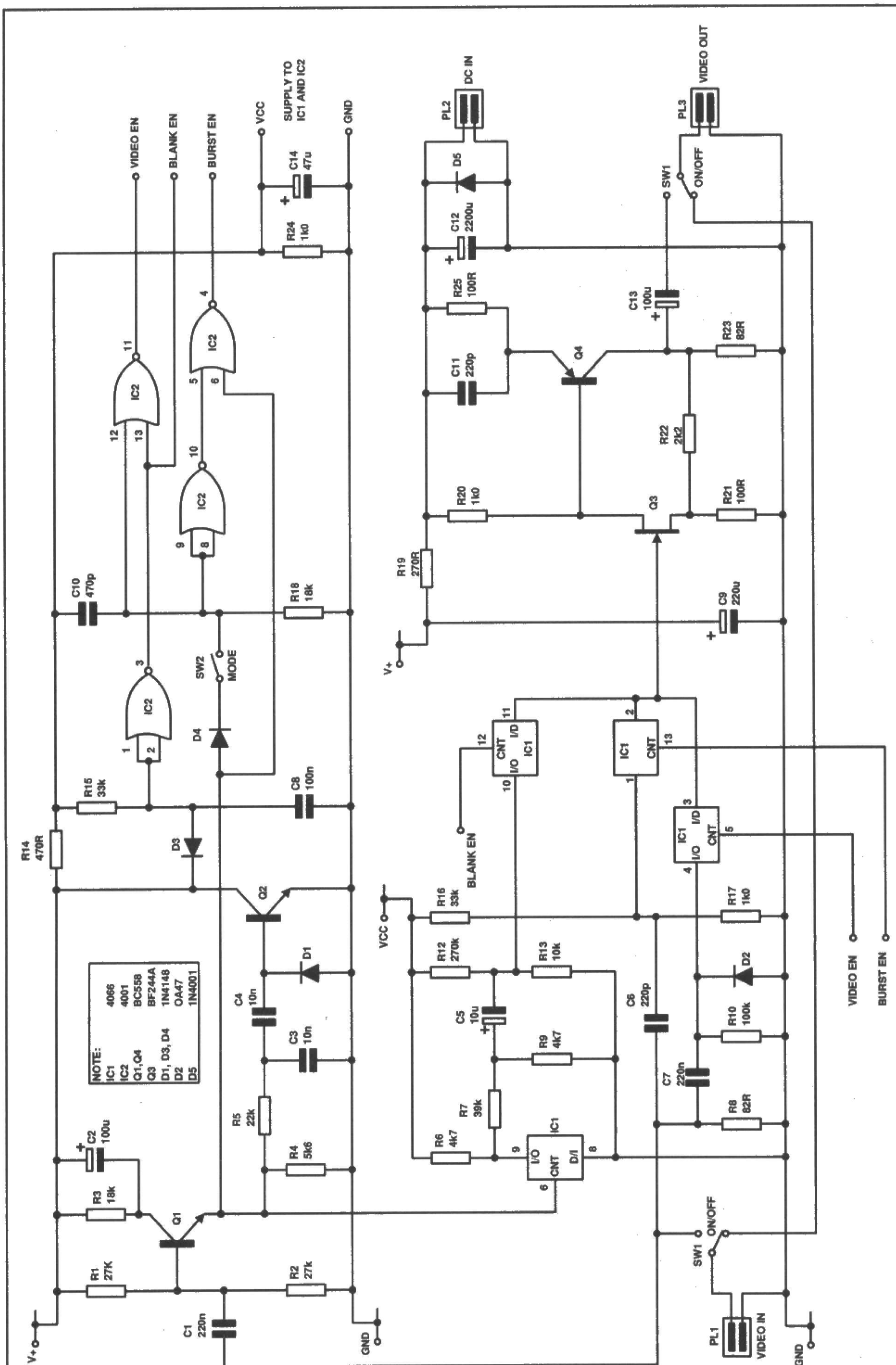
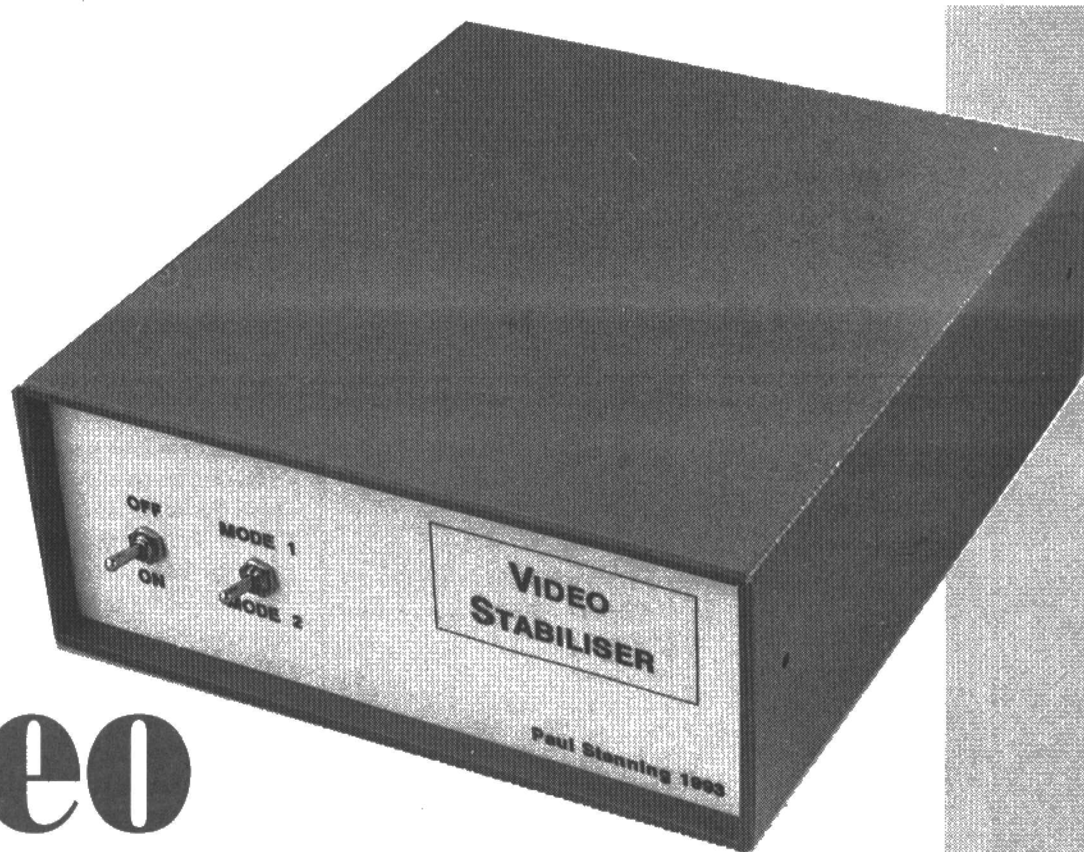


Fig. 1 Video Stabiliser circuit

Suffering from unstable TV images when playing video tapes? Solve the problem with Paul Stenning's circuit



Video Stabiliser

A friend of mine recently purchased a good second hand colour television at a bargain price. The reason for the bargain price became apparent some weeks later - the set would not give a stable picture when playing a video tape that has copy-protection, such as those hired from a video library.

It was at this point that I became involved. The television manufacturer's UK agent was aware of the problem, but could not offer a modification to resolve it! I did not feel inclined to delve into the innards of the television without information and my friend didn't really want to buy another set. The only remaining option was to design a device to remove the copy-protection from the signal before it reached the TV. The result is the Video Stabiliser described here.

Copy Protection

The principle of copy protection is to alter the video signal such that it can be displayed normally on a TV or monitor, but not recorded by a video recorder. By examining the signal with an oscilloscope, I found two areas where it is altered.

How It Works

The complete circuit diagram is shown in fig ?.

The video enters the unit via PL1. SW1 selects whether the circuit is enabled or bypassed. R8 terminates the input. The circuit around TR1 is a sync separator, the output across R4 pulses between 0V and 6V approx.

TR2 is fed by an integrator circuit to produce the frame sync. D5, R13 and C9 extend this over the Teletext area at the top of the screen. This is squared up by the logic gate to form the Blank Enable signal, which is high during this part of the picture.

If SW2 is closed, D6, C10 and R14 extend the line sync pulse over the colour burst. The non-extended sync is gated with this to produce the Burst Enable signal, which is high during the colour burst.

Video Enable is high whenever the other two enable lines are low and covers the normal video and sync part of the picture.

The Sync signal is inverted by IC1 and R6. This is then attenuated and set to a suitable DC level by R7, R9, R12, R13 and C5, and forms the blanked video signal.

The video signal is held with its base line at around 0V by C7, R10, and D2. This is the normal video. Note that D2 must be a germanium device.

C6, R16 and R17 remove all DC from the video signal and leave the chrominance and colour burst, biased a little above the 0V rail. This forms the chrominance signal.

These three signals are fed into analogue switches controlled by the enable lines. Only one switch is closed at a time and, consequently, the required signal is assembled. The result is buffered by the output amplifier (TR3, TR4 and surrounding components). C13 adds a little HF boost to compensate for losses earlier in the circuit.

A supply of 9V (+/- 1V) at 35mA is required, this does not need to be regulated since the current consumption is reasonably constant. A low cost unit built into a large 13A plug may be suitable - select one that can be left on indefinitely. If the voltage is selectable it may have to be set to 6V since the load is light.

Any ripple on the power supply output is removed by C12. D5 protects the unit against reverse polarity. The supply to the sync separator is further decoupled by R19 and C9.

Note that IC1 and IC2 are operated from a supply of about 6V (due to R14, R24 and C14). This is because the sync separator output only goes up to about 6V and a gate powered from the 9V rail would not respond to it.

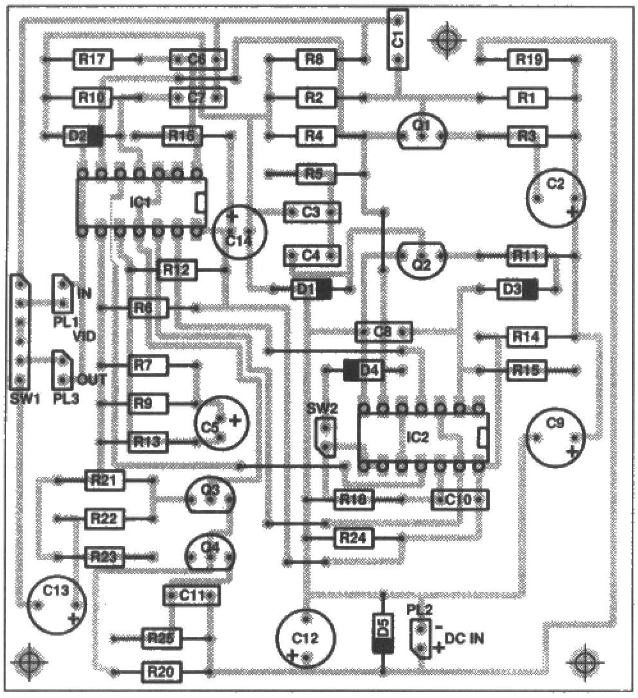
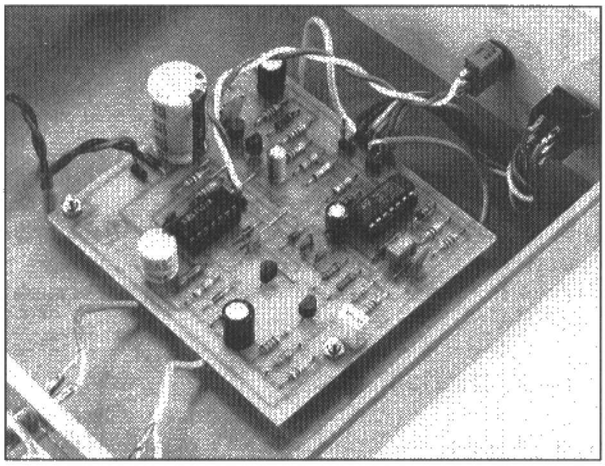


Fig. 2 Video Stabiliser component overlay



Firstly, the video level in the top section of the picture, normally reserved for Teletext information, is varied from black to peak white. Many video recorders use this part of the signal to set their automatic recording level, resulting in a signal with wildly varying amplitude that a television cannot successfully display.

Secondly, the colour burst has a DC offset in the last few lines of the picture. This is visible on some televisions as a dark section at the bottom of the screen. Many video recorders will confuse this with the frame sync signal, and lock onto it instead of the true frame sync.

The Video Stabiliser presented here will remove both of the above signal alterations and the prototype enabled my friend to enjoy his new toy. Removal of the colour burst offset is optional and selected by a front panel switch. A second switch enables the unit to be bypassed when not required.

The prototype unit was connected between the video output connector on the video recorder and the video input connector on the television. If it is being used with a television that does not have a composite video input socket, the signal must be modulated before being fed to the aerial socket. This can be achieved by connecting the unit between two video recorders.

Construction

The circuit is constructed on a single sided PCB, 84mm x 92mm. The component overlay is shown in fig ?.

Construction is reasonably straightforward. Start with the six wire links and then continue in the usual size order. IC1 and IC2 are both CMOS devices and IC sockets are recommended. D2 is a germanium diode, take care to ensure that it does not get too hot. Veropins or 0.1in header strip are recommended for the off-board connection.

Any case that is large enough to hold the PCB, sockets and switches would be suitable. A metal case may be preferable for screening but no problems were experiences with the prototype in its plastic box.

The interwiring is shown in fig ?. Screened cable may be used for the video connections, but this is not really necessary providing the wire is short.

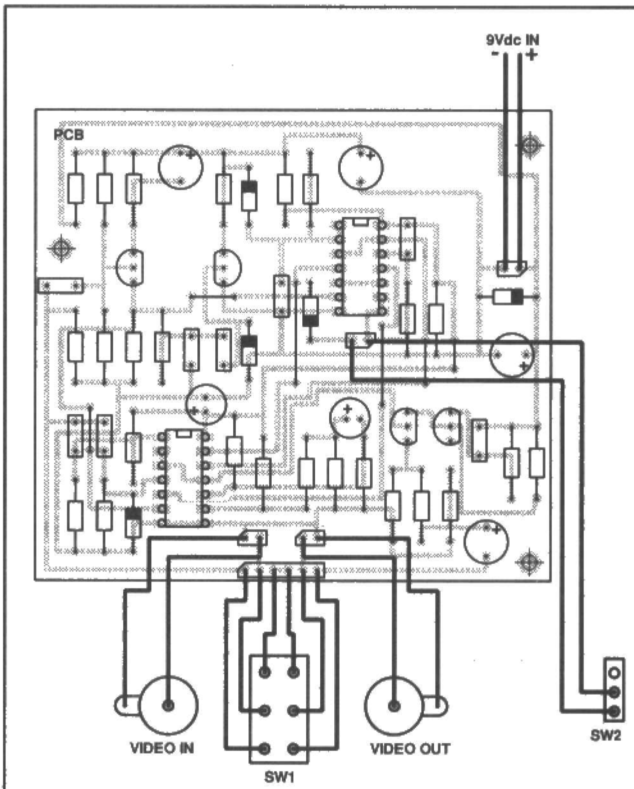
The two switches can be considered as optional - if one or both are not required link wires should be fitted in the PCB as required.

Testing

Provided that the unit is carefully constructed, there is no reason why it shouldn't work first time. If an oscilloscope is available, the output can be viewed when playing a copy-protected tape to verify that the offending signals have been removed. Otherwise simply connect the unit to your equipment and try it. Measure the voltage across C12, which must be 9V +/-1V. If the voltage is selectable on the PSU, try other settings to bring the voltage within range.

Alternatively, if the voltage is a little too high it may be possible to reduce it by connecting one or more 1N4001 diodes in series, in the positive connection to the PCB. Each diode will drop about 0.6V.

In some cases, a dark section may be visible at the top of the screen. This is caused by the delay produced by R15 and C8



Video Stabiliser interwiring

being longer than required. It appears that this delay differs slightly with different makes of 4001 IC, however the colour burst delay due to C10 and R18 is unaffected.

If this problem occurs there are two options. If you have a stock of ICs try some other 4001s to find one that's suitable. Otherwise try reducing the value of R15 to 27K or 22K and find the highest value where the dark section is not visible.

In Use

For normal viewing it may be preferable to set SW1 to bypass, to eliminate the inevitable slight signal degrading that this unit causes. When viewing a troublesome video film, the unit should be switched in. SW2 should only be closed if it proves necessary, since this may cause slight colour variation problems. For legal reasons please do not use this unit for any other purpose!

Paul Stenning

BUYLINES

All components are readily available and no buying problems are envisaged.

The electrolytic capacitors should be rated at 16V or greater and be radial types. The other capacitors should have a lead pitch of 0.2in (5mm), other types may fit if the leads are bent.

Before purchasing a power supply, check the latest Greenweld bargain list. They often list suitable types for about two or three pounds.

The PCB is available from the ETI PCB service, see page 60.

PARTS LIST

RESISTORS (All 0.25W 5% or better)

R1,2	27K
R3,18	18K
R4	5K6
R5	22K
R6,9,11	4K7
R7	39K
R8,23	82R
R10	100K
R12	270K
R13	10K
R14	470R
R15,16	33K
R17,20,24	1K0
R19	270R
R21,25	100R
R22	2K2

CAPACITORS

C1,7	220n
C2,13	100µ
C3,4	10n
C5	10µ
C6, 11	220p
C8	100n
C9	220µ
C10	470p
C12	2200µ
C14	47µ

SEMICONDUCTORS

IC1	4066
IC2	4001
TR1,4	BC558
TR2	BC548
TR3	BF244A
D1,3,4	1N4148
D2	OA47
D5	1N4001

MISCELLANEOUS

PL1,3	BNC Socket (or as required)
PL2	2.1mm Power Socket (or as required)
SW1	DPDT Miniature Toggle Switch
SW2	SPST Miniature Toggle Switch

PCB, Case, Power Supply (see text), Veropins, Wire, PCB Mounting Hardware, Video Cable and Connectors as Required

Microprocessor Fundamentals

Microprocessor chips form the central processing heart of every personal computer but what most people are not aware of is that they can now be found in virtually any piece of electronic equipment

What we have witnessed in the last decade has been an inexorable move away from pure hardware systems towards systems largely based upon software. Indeed this transition has probably been one of the most important technological developments of all time.

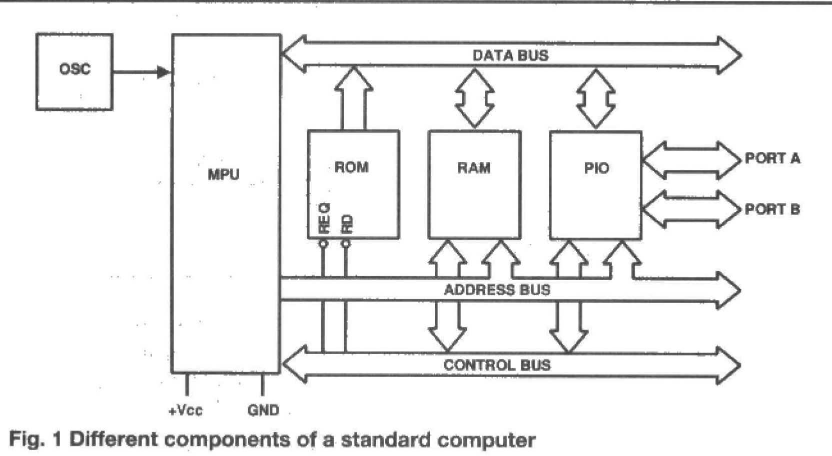


Fig. 1 Different components of a standard computer

Microprocessors in design

So why have designers turned away from designs based purely on electronics hardware to designs based largely upon software? One extremely important reason is flexibility. A design which relies to a large degree upon software can be changed by simply changing the code stored in an EPROM and with little need for extensive rewiring and new circuitry.

This is possible for the simple reason that we can define any electronic circuit as a 'black box' with input and output. Since the electronic circuit embodied in the 'black box' is a determinate machine, in other words one which behaves in a predictable manner, it is possible to create a table of relationships between input and output, a truth table. It does not matter whether a system is analogue or digital, we can still draw up such a table.

Any table of relationships between input and output, and thus any determinate machine, can be modelled using computer software. This is exactly what happens when we replace a hardware circuit with a microprocessor and software. The software models the circuitry it replaces and the interface circuitry provides the same inputs and outputs. Thus, from the outside the operation of a pure hardware system and an analogous software based system are exactly the same.

This gives the design enormous flexibility and means that it can be easily changed to meet changing demands from customers, and can equally easily be upgraded to create new higher priced versions. Thus a piece of equipment can be produced, with the same electronics circuitry, but different software to tailor it to the needs of different markets in different parts of the world, a factor which increases market competitiveness without increasing production cost.

The movement towards designs with a high software component also has another bonus. It is invariably simpler, with fewer chips, and can thus be produced more cheaply and more reliably. Again, features which emphasise the competitive edge which a microprocessor based design can give to a product.

Another important factor is reduced development time. With the availability of sophisticated programming languages and software tools, it is possible to create the software element of a design in a very short time frame. This contrasts with the time taken to develop and test a circuit, build prototypes, create the PC board and perhaps even create bespoke integrated circuits. A matter of weeks for the software and months for the hardware, factors which are reflected in the final cost, and the manufacturers' ability to rapidly identify and exploit a market.

Indeed, much of the drive towards the use of a large software component in the design of electronics systems has been a purely commercial one, but there is also the fact that as systems become increasingly more complex so it becomes much harder to design a pure hardware implementation which will reliably work. Without computers, at all levels, much of what we take for granted today would be impossible.

These are factors which apply as much to the amateur as they do to the manufacturer. Many of us are no longer content with simple projects, we want to do something more ambitious, something with more complex functions, but we do not want it to be much more complex to design, build or test and neither do we want it to be much more expensive. The solution

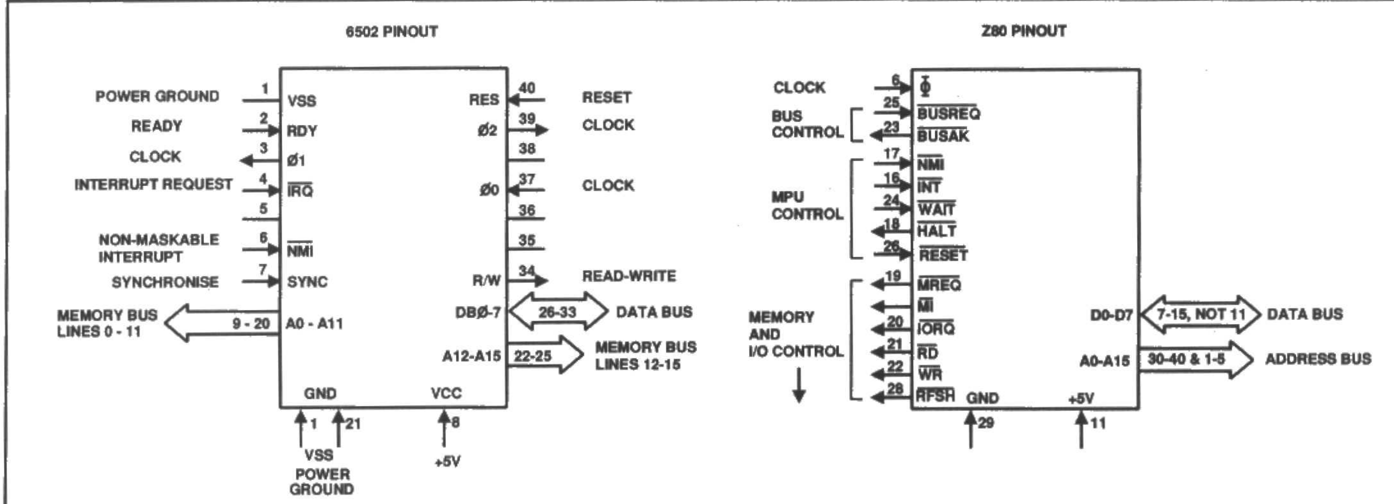


Fig. 2 Pin outs of two common eight bit microprocessor chips

is to follow the manufacturers' lead and incorporate software into the design. In other words, to use a microprocessor as the basis of any reasonably complex electronic system design.

What is a microprocessor?

Before we can actually use microprocessors in building a device, we need to be able to answer the question, what exactly is a microprocessor? The answer is not that simple, for a microprocessor is an extremely complex device, but we can broadly say that it is the component which executes the sequence of instructions which make up a computer program, instructions which are stored in memory and which manipulate data. This data might also be stored in memory, or obtained from, or sent to, special input/output circuits, which might in turn be connected to keyboard switches, lights, relays, displays, etc..

This leads us to the fact that a microprocessor is only one part of a processing system. Besides the microprocessor there is memory circuitry, input/output circuitry and general purpose control circuitry. To work, any system has to have all these different components, as shown in Fig 1.

Of course some microprocessors, the so called microcontrollers, have all these different components integrated onto a single IC, which means that to the casual observer it looks like a self contained system. These single chip systems are popular with consumer goods manufacturers because they are cheap and reliable, but by and large the type of microprocessor system which most amateurs will be using will be based upon a circuit which includes the processor chip, memory chips, and I/O chips.

Inside the microprocessor

If we look at a typical small, low power microprocessor chip, such as the 6502 or Z80 (simple eight bit processors whose pin outs are shown in Fig 2.) we can clearly see that the connections to the chip fall into three distinct categories. There are eight data lines, sixteen address lines and control and power supply lines, forty pins in all.

The data lines are used to carry a parallel byte of data from memory location to processor and back again. The actual memory location being selected by the sixteen address lines, and since computers all work on the binary system the sixteen address lines mean that for a processor like the 6502 there can be a maximum of 216 or 65,536 possible memory locations.

The simplest operation that a processor is called upon to do is to fetch a byte of data from a specified memory location. To do this the processor needs an internal sixteen bit pointer

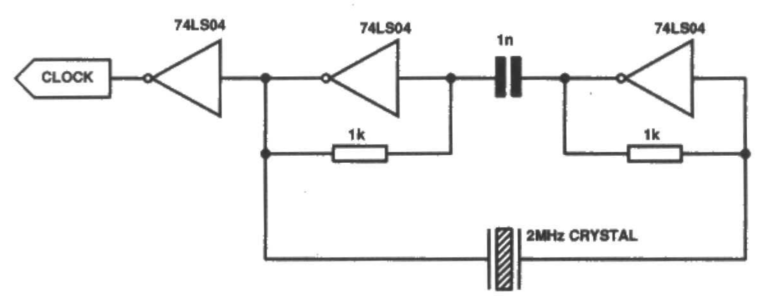


Fig. 3 Crystal controlled oscillator circuit

which can be set to point to one of the 65,536 possible locations. This pointer is stored in a special type of memory location within the processor called a register and this particular register is called the program counter.

The sixteen bit program counter is connected directly to the processor address lines and can be set to any desired value by a range of different program commands. So if the program directs the processor to read the contents of a specified memory location, the address of that location is put into the program counter. At the same time, a command is sent to the memory location to say that its contents are to be read. This results in the data lines being set to the value stored in the specified memory location.

The data on the data lines can be transferred to one of a number of different data registers within the processor, the choice depending upon the program command. The logical and arithmetic operations of the processor are performed between these different data registers by circuitry known as the arithmetic logic unit, again under the direction of the program commands.

So with a simple processor like the 6502, the Z80, or the 6800, we can reduce the conceptual internal contents down to

a handful of different data registers, a program counter, an arithmetic logic unit and some control circuitry. A conceptual model of a 6502 together with a description of the program cycle is shown in the box on this page.

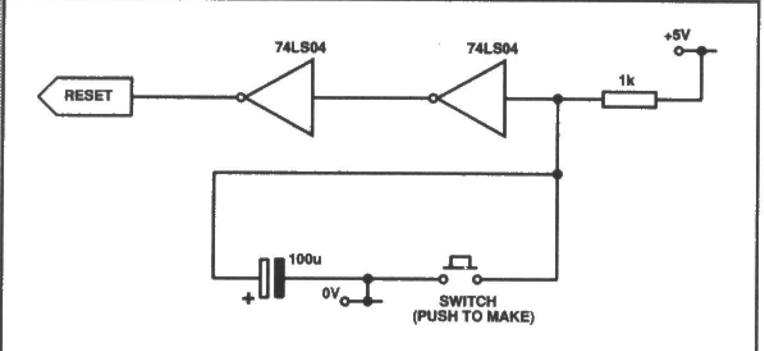


Fig. 4 Simple push button reset circuit

The microprocessor at work.

A microprocessor works by following a sequence of coded instructions, the program. At this stage we will not consider the actual detailed structure of a program, or the techniques of writing a program, this will be looked at in a later article. However, it must be emphasised that the type of program we are talking about in this series is not the familiar Basic, Pascal, or C program used on a PC, but assembly language, or machine code, programming.

In assembly language programming, the programmer is working at a level which is far closer to the actual hardware. It involves the use of instructions which specify exact memory locations and specific processor registers. This does not mean to say that one necessarily needs to write a program for a simple microprocessor system using assembly code, it can be written with the aid of a high level language compiler, such as C++, although in so doing the programmer does lose a lot of control, as well as having a slower and less well optimised piece of code. Wherever possible, writing code in assembly language is recommended for this type of application.

The machine code instructions which make up the program are stored in memory in a specified order and are accessed by the program counter one after the other, under the ordered control of a system clock. A clock, by which we mean a regular sequence of pulses rather than a device which gives us time and date, is of vital importance to the functioning of any type of computer system. Without such a clock it would be impossible for the processor to synchronise the moving and manipulation of data and without such synchronisation, the processor would simply not work. The commonly used 6502 has a 2MHz clock, which means that each clock cycle takes just half a microsecond.

Every clock cycle, the processor performs a function which is determined by the program instruction stored in a memory address pointed to by the program counter. With a simple instruction, it might be completely executed in one clock cycle, but the majority of instructions take two, three or even four cycles to complete their execution. The box on page xx shows the relationship between clock cycles and program instruction execution.

The starting memory location of the program which is to be executed can be determined in one of two different ways, either by the use of a hardware system Reset, or a hardware Interrupt. The Reset and Interrupt are two of the most important control inputs to the microprocessor chip.

The Reset as its name implies is used to reset the program counter to the beginning of a program so that it starts all over again, whereas the Interrupt, and there is frequently more than one type of interrupt on a microprocessor chip, is used to halt execution of the current program and initiate the execution of another program. Only when that program has been completed will execution of the first program resume at the same point that the interrupt occurred.

When either an Interrupt or a Reset occurs, the system needs to know the exact starting address of the respective piece of code. It does this with the aid of a jump vector stored as a sixteen bit address at a pair of predefined locations in memory. On the 6502 the Reset vector is located at the hexadecimal locations FFFC and FFFD and the IRQ Interrupt at locations FFFE and FFFF. It is these jump vectors which contain the actual starting address of the program code.

The essential control circuits.

There are thus three basic control inputs that are to be found on every microprocessor. They are the clock input, the system Reset and one or more system Interrupts, each of which requires its own small piece of circuitry. In addition, there are the power inputs, which on most modern microprocessor systems consist of little more than 5V at 1A or less.

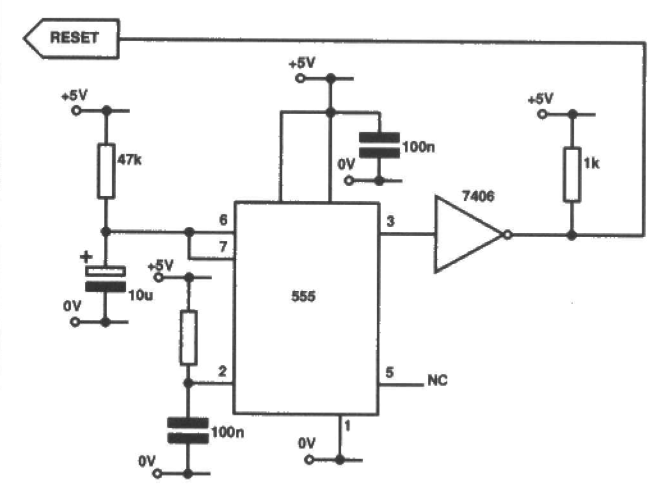


Fig. 5 Power up reset circuit

Let's first look at the clock circuit, since this is the most complex. This could be any circuit capable of producing a suitable square wave output with a frequency within the range specified by the processor manufacturers. In practice, however, most microprocessor clocks are derived from a crystal controlled oscillator circuit, such as that shown in Fig.3.

The reason for this is that a great many applications require accurate timing functions to be performed by the software. Such time related functions could range from the generation of an analogue waveform of a specific frequency to controlling the speed of an electric motor. With a crystal controlled clock there is a known frequency from which time can be calculated and there is no problem of variation in frequency due to

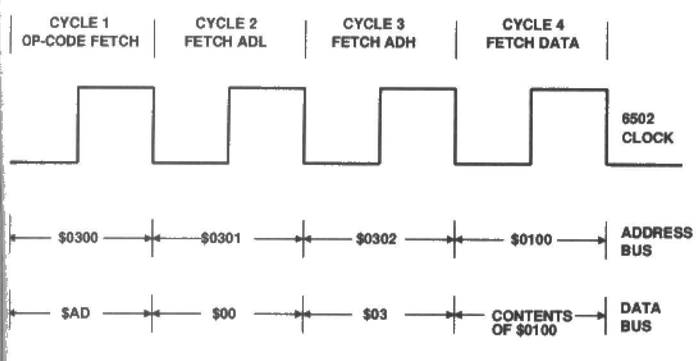
The microprocessor program cycle

The best way to show how a processor executes instructions is to follow a short sequence of instructions using the conceptual model of the 6502 shown above.

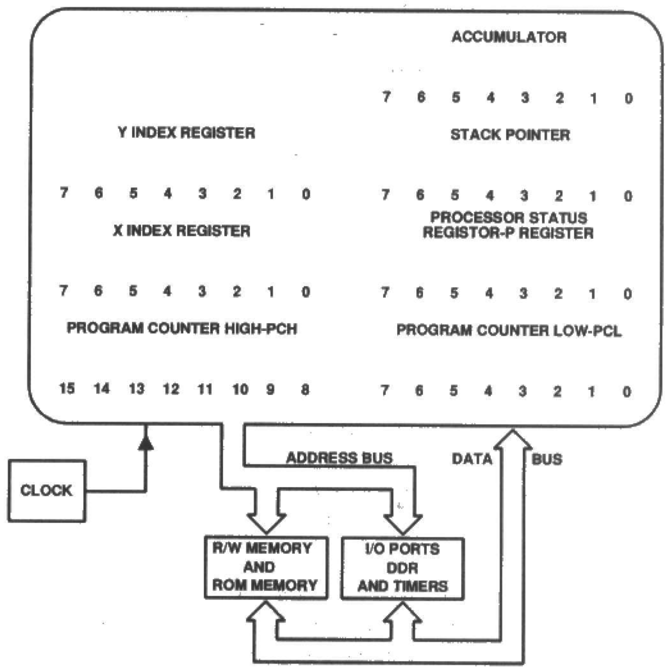
The following is a typical piece of code stored at starting address $0300, which involves fetching a byte of data stored in location $0100 and placing it in the processor's accumulator:

Location	Contents	Action
0300	AD	fetch the contents of the location
0301	00	whose address is $0100, and place
0302	01	it in the accumulator

If we look at the clock cycle sequence involved in executing this small piece of code then we will find that it looks like this:



CTIVITY ON ADDRESS BUS AND DATA BUS BY CLOCK CYCLES DURING LDA INSTRUCTIO



MODEL OF 6502 MICROPROCESSOR

We can break this down into a number of steps, as follows:

1 - First clock cycle, the contents of the program counter, $0300, are placed on the address bus and the processor reads the op code on the data bus, the program counter is then incremented to $0301.
2 - Second clock cycle, the contents of the program counter, $0301, are placed on the address bus and the lower portion of the address, the ADL, where the data is stored is then fetched from location $0301 via the data bus. The program counter is incremented to $0302.
3 - Third clock cycle, the contents of the program counter, $0302, are placed upon the address bus and the upper portion of the address, the ADH, where the data is stored is then fetched from location $0302 via the data bus. The program counter is incremented to $0303.
4 - Fourth clock cycle, the values fetched from ADH and ADL are placed in the program counter, thus the value $0100 appears on the address bus. The processor then fetches the contents of that byte via the data bus and stores the value in the accumulator, the program counter is restored to its previous value, $0303.

This is just a short fragment, that involves the execution of just one single instruction. In an actual program the instruction sequence may well involve many thousands of such operations.

changes in temperature.

The Reset on most systems will be connected to a switch, usually a simple push button type, although it might also be derived from a circuit which automatically creates a Reset condition on system power up. The choice depends upon the application. The Reset line is normally held at a logic high, in other words tied to the +5V rail via a 1K resistor. When it is pulled low for a minimum of two clock cycles, then processor operation is halted. The actual Reset occurs on the transition back from low to high.

The Reset circuit shown in Fig.4 is a very simple push button version. The switch used is a normally open non-latching type, and the two 7404 buffer inverter gates are there simply to ensure that the correct logic levels are available, as well as removing switch bounce and squaring up the pulse edge.

The Reset circuit in Fig.5 is a more complex circuit which generates a power up reset. It is based around the 555 timer chip and simply relies on the power coming on to act as the trigger. A suitable delay is then generated by the 555 before it sends the Reset line high, to ensure that the system has settled down after being switched on.

As far as the interrupt lines are concerned they need no special circuitry since the inputs on these lines are, by and large, generated by the system I/O circuitry. However, for proper operation these lines should always be tied to the appropriate logic level voltage rail via a 3.3Kohm resistor. On both the Z80 and 6502 they would be tied to the +5V supply. They are then pulled low by the I/O circuit.

Next month.

In the next part in this series we shall be looking at the organisation of a microprocessor's memory address space and techniques for address decoding.

Alex Stewart

Further reading.

There are a great many books on programming and using microprocessors and a look in your local library and book shops is well worth while. The following are a couple of titles worth examining:

Microcomputer Interfacing. by Mike Cavenor and John Arnold. Published by Prentice Hall, price £18.95.

Programming the Z-80. by Rodnay Zaks. Published by Sybex Books, price £23.95

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E9312-3	**PC I/O Board**	**N**
E9312-4	**Video Stabiliser**	**G**
E9312-FC	**Transistor Tester**	**F**

PCBs for the remaining projects are available from the companies listed in Buylines.
Use the form or a photocopy for your order. Please fill out all parts of the form. Make sure you use the board reference numbers. This not only identifies the board but also tells you when the project was published. The first two numbers are the year, the next two are the month.
Terms are strictly payment with order. We cannot accept official orders but we can supply a proforma invoice if required.
Such orders will not be processed until payment is received.

E9207-FC	Surround Sound Decoder	F
E9208-1	Dynamic Noise Limiter	F
E9208-2	Touch Controlled Intercom (2 boards)	H
E9208-3	MIDI Keyboard	K
E9208-FC	Battery charger	F
E9209-1	Intercom for light aircraft	H
E9209-2	Alarm protector	C
E9209-3	Temperature controller	M
E9209-FC	45W Hybrid power amp	F
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E2910-2	Rapid Fuse Checker	E
E9210-3	Heartbeat/Audio Listener	E
E9210-FC	Wizards Hat	E
E9211-1	Electronic Die	E
E9211-FC	Car Alarm	F
E9212-1	Digital Circuit Tester	F
E9212-2	Communications Link by RS232	L
E9212-FC	Mains Inverter	E
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E9301-FC	Infra Red Receiver	F
E9302-1	EPROM Programmer (2 Sided)	N
E9302-2	Sound to MIDI Board	L
E9302-3	Puddle Tec	E
E9302-4	DiscoAmiga Light Selector	H
E9302-FC	Infra Red Transmitter	E
E9303-1	Ni-Cd Battery Charger	E
E9303-2	IC Tester	E
E9303-3	Disco Amiga (motor driver board)	H
E9303-4	Direct Conversion Reciever (2 Sided)	N
E9303-FC	LED Stoboscope	F
E9304-1	Solo Mic Pre-Amplifier	F
E9304-2	Multimate Tester	C
E9304-3	The Keepsafe Alarm	F
E9304-4	Proving Unit	E
E9304-5	Infra Guide Receiver Module	C
E9304-6	Infra Guide Transmitter	F
E9304-FC	(AutoMate) Peak Program Meter	F
E9305-1	Pentacode Main Board	F
E9305-2	Pentacode Relay Board	F
E9305-4	Vibration Detector	D
E9305-FC	The Fuzztone	E
E9306-1	Graphic Equaliser	F
E9306-2	Super Spooker	H
E9306-3	Middle & Side Stereo Coding	D
E9306-FC	The Chaperon	F
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E9307-2	Mind Trainer	F
E9307-FC	Microwave Monitor	F
E9308-1	Window Monitor (4 Boards)	K
E9308-2	Alternative 12V Supply	M
E9308-3	Single Channel Lumitec	E
E9308-4	Four Channel Lumitec	H
E9308-FC	Twi-light Zone	F
E9309-1	RF Signal Generator	F
E9309-2	MIDI Analyser CPU Board	K
E9309-3	MIDI Analyser Display Board	J
E9309-4	Metronome	G
E9310-1	Hot Wire Cutter	F
E9310-2	Electronic Picture	H
E9310-3	Sega Box	J
E9310-4	Transistor Amp (2 Boards)	N
E9310-5	Home Minder (2 Boards)	N
E9310-FC	Continuity Tester	D
E9311-1	Car Alarm	G
E9311-2	MIDI Change Pedal (double sided)	H
E9311-3	RC Engine sound	J
E9311-4	PSU Monitor	N
E9311-FC	RF Hound	D

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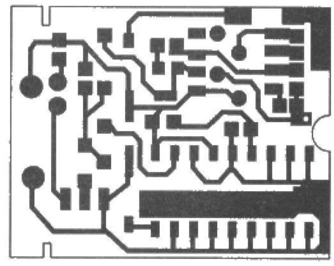
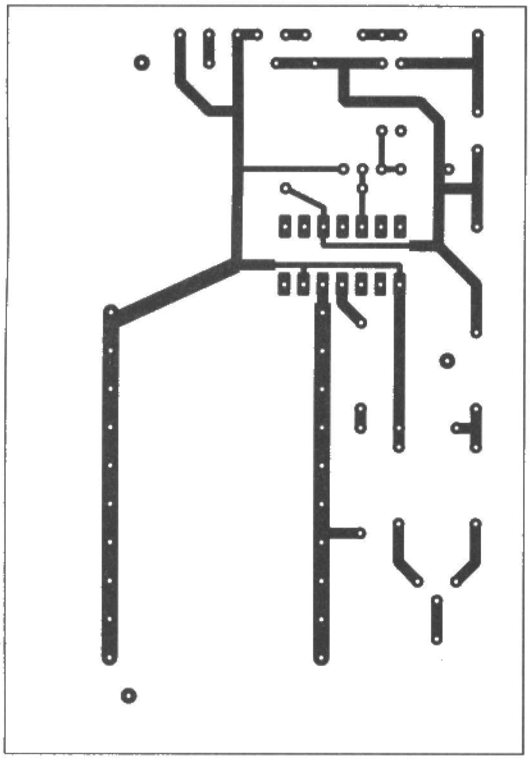
PCB Foils

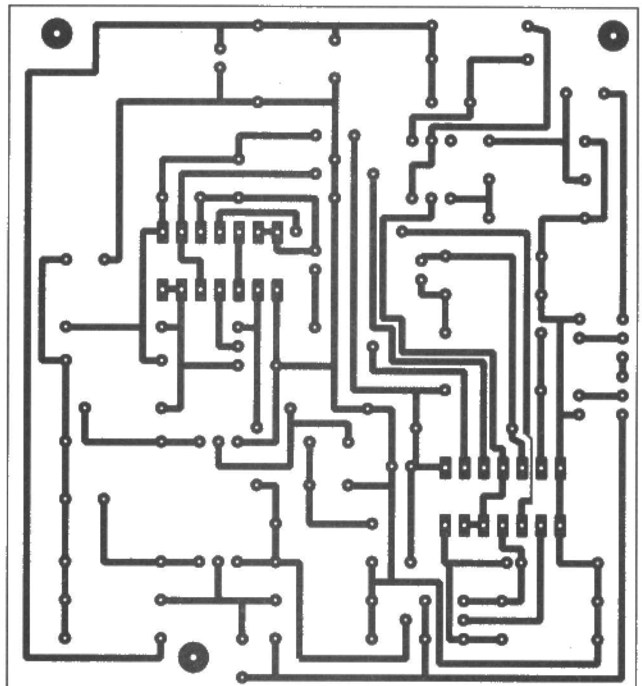
The PCB foil patterns presented here are intended as a guide only. They can be used as a template when using tape and transfer for the creation of a foil



Car Alarm



NiCd Battery Charger

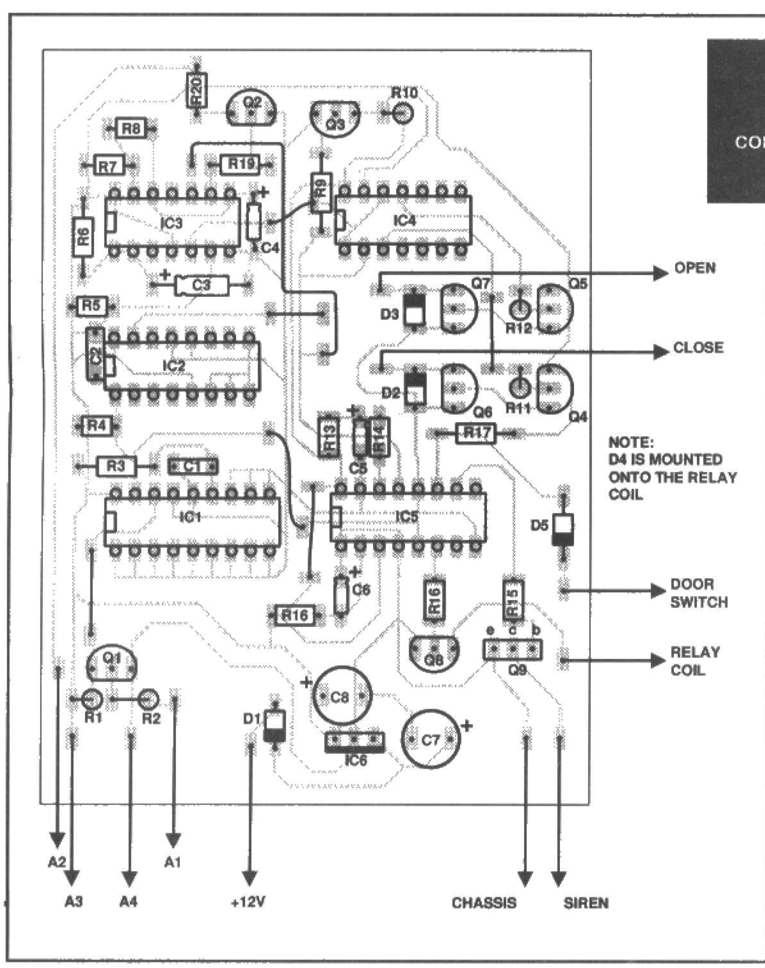


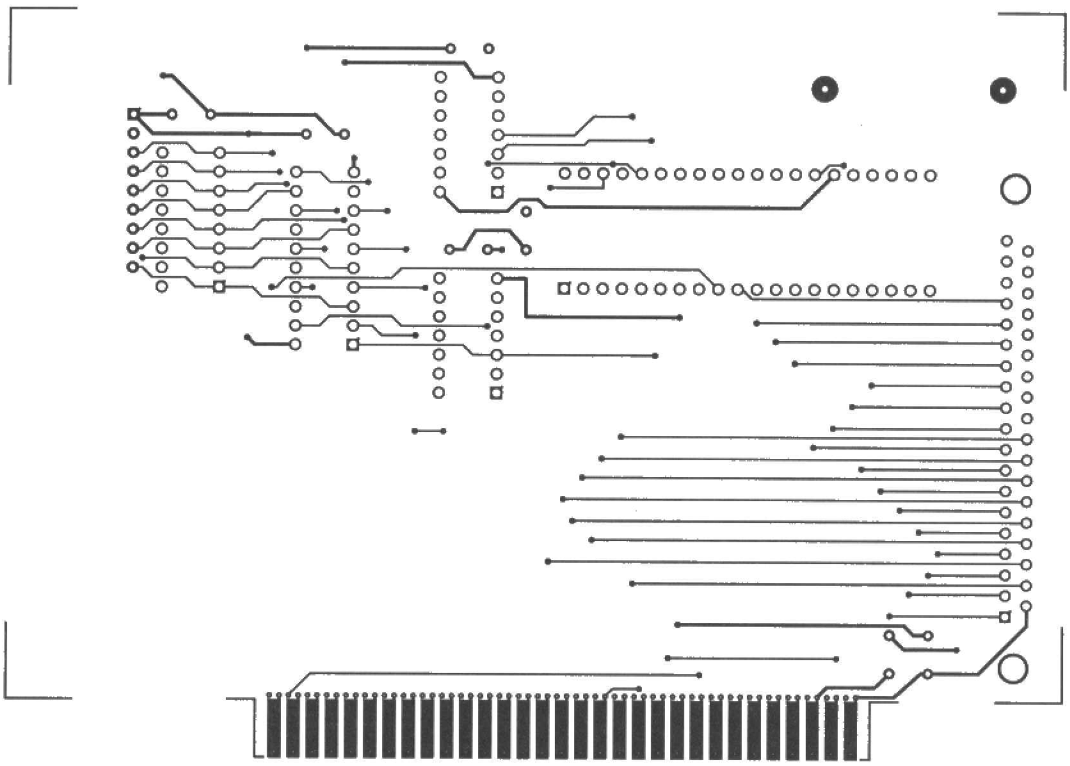
Video Stabiliser

↑ WRONG WAY ROUND SEE ETI FEB 1996 FOR CORRECTION

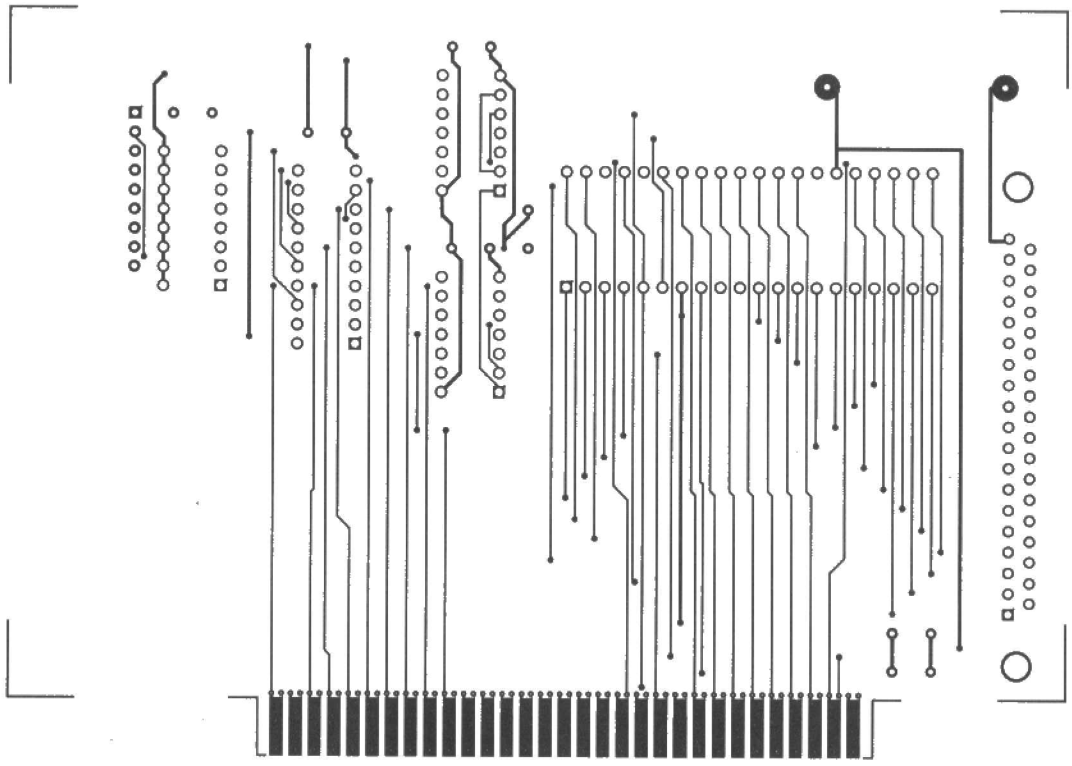
OOPS

Last month we neglected to print the component overlay for the car alarm. We reproduce it here

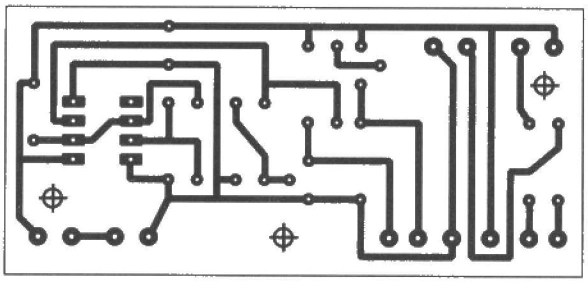




PC I/O Board - Solder side



PC I/O Board - Component side



Transistor Tester

OPEN FORUM

Technology and society

We live in a society which relies exclusively upon science and technology for its existence, indeed for its very survival. Without technology, and the scientific research from which it springs, we in the developed nations of the world would be plunged into a standard of living which would, in most cases, be worse than that of third world countries.

It is technology which has allowed us to have dense urban populations. Populations which are fed, clothed, educated, amused and kept warm by high technology manufacturing, power generation, communications, agriculture, transport, and mining. Conversely, it is dense urban populations which have given society the pool of skilled intellect which has created this capability and which can further develop the technology on which our society is built. Unless we are to have a society plagued by disease, starvation, and poverty, we must continue to use our intellect to make our lives better. That means using everything that science and technology can offer us.

As a society we should not be deriding and criticising scientists and technologists, with the man in the street all too frequently regarding them collectively as either mad or irresponsible. Instead, society as a whole should be supporting them to the full. We should be regarding our scientists, our technologists, and our engineers as examples of the modern Columbus, explorers of uncharted realms of knowledge where all manner of riches may be found that will benefit all of us.

So why is it that scientists, technologists, and engineers have such a lowly position in society today, despite the fact that that same society relies upon them for its very existence? A large part of the reason, I suspect, is simply that people in the past have expected too much from them.

To err is human

Unfortunately scientists, technologists, and engineers are not infallible and all knowing, they make mistakes like anyone else, They are human and can be used by the greedy, the power hungry and the unscrupulous. But perhaps their worst failing is their isolation from the mass of the population, their all too common inability to communicate with the man in the street. In the absence of such a dialogue, the common man, in his ignorance, becomes prey to fears and phobias about science and technology.

This is where those of us who understand something about science and technology can do something to help bridge this gap in communications and confidence. We can do this by showing those around us that science and technology is not the exclusive realm of that media image of strange, absent minded and slightly crazy people in white coats. People who create lethal anti-social devices in expensive laboratories.

We must show that science, engineering and technology can also be about ordinary people using the knowledge that mankind has acquired to create things which can give them, and others in society, a better quality of life. Enthusiasts, hobbyists, the readers of magazines like ETI, embody a huge creative potential which can not only help society in general but also restore the reputation of engineers, scientists, and technologists as competent, thoughtful, caring individuals.

In this issue of ETI we look at one simple way in which readers can use their expertise to help less fortunate members of society. In this case, a computer keyboard system for people suffering from severe motor disability. With this simple little project which, including the PC, would cost no more than a couple of hundred pounds, it is possible to give such people a lot more freedom than they would otherwise have.

This is just one example of how readers of ETI can use their expertise in electronics and technology to give others a better quality of life. There are a host of other examples. We could create a simple speech synthesis system to help those with speech disabilities to talk. We could help build and install intercom/alarm systems in the homes of old people. We could devise alternative energy power systems for use in third world countries. The list is endless.

All that is needed is for those of us with the expertise to get together with the charities and the carers. Together, it is possible to achieve far more, for far less, than can be done using commercial equipment and commercial expertise. At ETI we will be supporting these kinds of ideas, we will be publishing projects which can be used by individuals, by organisations and by schools to help others within their community to lead fuller lives. Through CIX we will also be providing readers with the means to communicate ideas with each other.

Let's show the world that as scientists, technologists and engineers, we are not a bunch of anti-social nerds, but caring and responsible people who want to use their skills and knowledge to make the quality of life better for everyone.

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